

## Appendices



Photo Courtesy of Virginia Save Our Streams

# **Appendix 1**

## **Contacts**

## Virginia Citizen Water Quality Monitoring Program Contacts

Alliance for the Chesapeake Bay  
<http://www.AllianceChesBay.org>  
[lwoodworth@acb-online.org](mailto:lwoodworth@acb-online.org)  
(804) 775-0951  
PO Box 1981  
Richmond, VA 23218

Virginia Department of Environmental Quality  
<http://www.deq.virginia.gov/cmonitor>  
[jebeckley@deq.virginia.gov](mailto:jebeckley@deq.virginia.gov)  
(804) 698-4025 or toll free in Virginia (800)  
592-5482  
P.O. Box 10009  
Richmond, VA 23240

Virginia Department of Conservation &  
Recreation  
<http://www.dcr.virginia.gov>  
203 Governor St., Suite 206  
Richmond, VA 23219

Virginia Save Our Streams Program  
<http://www.vasos.org>  
[vasosoffice@vasos.org](mailto:vasosoffice@vasos.org)  
(804) 615-5036 toll free (888) 656-6664  
P.O. Box 8297  
Richmond, VA 23226

## Regional citizen monitoring groups

Appomattox River Water Quality  
Monitoring Program  
Clean Virginia Waterways  
Longwood University  
<http://www.longwood.edu/cleanva>  
[Cleanva@longwood.edu](mailto:Cleanva@longwood.edu)  
(434) 395-2602  
Dept. of Natural Sciences  
Farmville, VA 23909

Assateague Coastal Trust  
<http://www.actforbays.org>  
[mail@actforbays.org](mailto:mail@actforbays.org)  
(410) 629-1538  
Box 731  
Berlin, MD 21811

Audubon Naturalist Society  
<http://www.audubonnaturalist.org>  
(703) 803-8400  
Web Sanctuary  
P.O. Box 51  
Clifton, VA 22207

Ferrum College  
Smith Mountain Lake and Claytor Lake Water  
Quality Monitoring Programs  
<http://www.ferrum.edu/waterqual/sml/index.htm>  
[djohnson@ferrum.edu](mailto:djohnson@ferrum.edu)  
Ferrum, VA

Friends of the Shenandoah River  
<http://www.fosr.org>  
[friendsofshenandoahriver@gmail.com](mailto:friendsofshenandoahriver@gmail.com)  
(540) 665-1286  
Shenandoah University  
1460 University Drive (Gregory Hall)  
Winchester, VA 22601

James River Association  
<http://www.jamesriverassociation.org>  
[keeper@jrava.org](mailto:keeper@jrava.org)  
(804) 730-2898  
P.O. Box 909  
Mechanicsville, VA 23111

Lake Anna Civic Association  
<http://www.lakeannavirginia.org/LEEP/waterquality.html>  
P.O. Box 217  
Lake Anna, VA 23117-0217

Loudoun Wildlife Conservancy  
<http://www.loudounwildlife.org>  
P.O. Box 2088  
Purcellville, VA 20132-2088

Mattaponi and Pamunkey Rivers Association  
<http://www.mpra.org>  
(804) 769-0841  
P.O. Box 157  
Walkerton, VA 23177

McClure River Restoration Project  
<http://www.lpswcd.org/MRRP/MRRP.htm>  
130 Clintwood Main Street  
Clintwood, VA 24228  
(276) 926-6621

Northern VA Soil & Water Conservation  
District  
<http://www.fairfaxcounty.gov/nvswcd/monitoring.htm>  
[jcornell@gmu.edu](mailto:jcornell@gmu.edu)  
(703) 324-1425  
12055 Government Center Pkwy #905  
Fairfax, VA 22035-5512

RappFLOW  
<http://www.rappflow.org>  
[bev\\_hunter@earthlink.net](mailto:bev_hunter@earthlink.net)  
540-937-4038

Upper Rappahannock Watershed Stream  
Monitoring Program  
<http://www.rappmonitor.va.nacdn.net>  
[rappmonitor@yahoo.com](mailto:rappmonitor@yahoo.com)  
(540) 937-3934

## **Appendix 2**

### **Letter of Agreement**

**2006 Partnership Agreement  
To Implement the Virginia Citizens Water Quality Monitoring Program**

**Purpose**

This document continues the collaborative partnership, which began in 1998 and was reaffirmed in the 2002 Letter of Agreement, between the Alliance for the Chesapeake Bay (the Alliance); Virginia Department of Environmental Quality (DEQ); Virginia Department of Conservation and Recreation (DCR); and the Virginia Division, Izaak Walton League of America, Save Our Streams Program (VA SOS) for the purpose of supporting and implementing the Virginia Citizen Water Quality Monitoring Program.

While many government agencies and other organizations participate in and support this cooperative effort, this Agreement defines the roles of the above agencies and organizations, as well as the Virginia Citizens for Water Quality (VCWQ) and the Virginia Water Monitoring Council (VWMC), in the implementation of the Virginia Citizen Water Quality Monitoring Program.

**Shared Goals**

We recognize that cooperative efforts strengthen citizens' commitment to water quality and therefore enhance Virginia's ability to protect and restore the Commonwealth's water quality.

Therefore, we resolve to support the Virginia Citizens Water Quality Monitoring Program and work together towards the following goals:

1. To have a comprehensive understanding of all water quality monitoring efforts in the Commonwealth, including types, location, and results.
2. To ensure that citizen water monitoring data can be used to supplement agency monitoring efforts in Virginia's 305(d)/303(b) Integrated Water Quality Assessment Report and help to evaluate the effectiveness of nonpoint source pollution prevention measures including Tributary Strategies and TMDL implementation and to document the listing and de-listing of impaired waters.
3. To encourage citizen monitoring efforts by providing resources, when available and practicable, including training, supplies and equipment, funding and technical assistance and to ensure that delivery of the resources by the partners is coordinated whenever possible.
4. To support citizen water quality monitoring activities by supporting the many uses of data including for the following: education and outreach; baseline data to establish background conditions and prioritize monitoring needs; information to help with local land use decisions; alerting unusual conditions resulting from land use or resource management; and documenting water quality improvement projects.
5. To promote coordination and collaboration among organizations involved in citizen water quality monitoring activities so that efforts complement each other.

6. To provide user-friendly access to and effectively disseminate water quality information and data between the partners and the public.
7. To encourage volunteer citizen monitors to obtain the highest quality-controlled and quality-assured data that are appropriate for its intended uses.

### **Partner Responsibilities**

#### **Alliance for the Chesapeake Bay**

The Alliance provides assistance to watershed groups, citizens, and citizen organizations by providing training and organizational development in order to build restoration capacity at the local watershed level. The Alliance provides training in water quality monitoring methods; provides quality assurance oversight of data and methods for citizens and watershed groups participating in the Alliance's quality assurance program; and identifies new opportunities for citizen monitoring and assessment activities. While the mission of the Alliance is to protect and restore the Chesapeake Bay watershed, the Alliance is committed to supporting all citizen water quality monitors in the Commonwealth of Virginia. The Alliance maintains a public, web-based database of citizen monitoring activities, from which quality assured data are input annually to DEQ for use in assessment reports.

#### **Virginia Citizens for Water Quality**

The mission of VCWQ is to coordinate citizen water quality monitoring efforts and methodologies; to provide a funding mechanism for citizen water quality monitoring; and to promote watershed, water quality, and stream health issues. Through the VCWQ emailing list-server, VCWQ will provide a central place for agencies and other interested parties to distribute water quality-related information. VCWQ will maintain a comprehensive list of citizen water quality monitoring activities in Virginia on the VCWQ website. VCWQ will also host meetings twice a year to facilitate training opportunities and information sharing. VCWQ will utilize the annual summit to identify watershed priorities and needs as identified by the citizen water quality monitors. In addition, VCWQ will provide leadership in the effort to continue and expand funding sources for citizen water quality monitoring.

#### **Virginia Department of Conservation and Recreation**

As part of the Department's statewide responsibilities, DCR will continue to provide technical expertise and general information on matters concerning nonpoint source pollution. Specifically, DCR will lead the development and implementation of Tributary Strategies and Chesapeake 2000 commitments and, in cooperation with DEQ, will provide technical expertise and general information on Total Maximum Daily Load development and implementation. DCR will promote the use of citizen data to meet the Commonwealth's water quality data needs and will assist in identifying appropriate uses for citizen-generated data. DCR will promote the delivery of citizen stewardship activities on a watershed basis and will work to identify new opportunities for citizen stewardship efforts. DCR will work to engage citizens and citizen organizations in water quality monitoring and related stewardship activities. DCR will continue to provide technical expertise and general information on grant writing, sources of funding, public outreach techniques, organization development, and marketing.

### **Virginia Department of Environmental Quality**

As part of the Department's statewide responsibilities, DEQ will provide technical expertise and general information on matters concerning point source pollution and water quality. In cooperation with Department of Mined Land Reclamation and DCR, DEQ will provide technical expertise and general information on Total Maximum Daily Load development and implementation. DEQ will continue to provide technical expertise and general information about monitoring water quality, including monitoring protocols, planning water quality monitoring programs, existing agency monitoring locations, site selection, data management, and quality assurance and quality control measures and procedures. DEQ will maintain the *Virginia Citizens Monitoring Methods Manual* and may provide citizen water quality monitoring grants to support citizen efforts. In addition, DEQ will develop and maintain an online database where citizen groups, and other monitoring organizations, can store and retrieve water quality data. DEQ will promote the use of citizen data to meet the Commonwealth's water quality data needs and will assist in identifying appropriate uses for citizen-generated data. DEQ will continue to assist in identifying new opportunities for citizen stewardship efforts.

### **Virginia Save Our Streams**

VA SOS will continue to provide training to citizen monitors in water quality monitoring methods, provide quality assurance oversight for participating citizens, and assist in identifying new opportunities for citizen stewardship activities. VA SOS will continue to promote citizen stewardship efforts and will assist in locating citizens and citizen organizations desiring to participate in citizen water quality monitoring and related activities. VA SOS will assist organizations in identifying sources of funding and organization development.

### **Virginia Water Monitoring Council**

The VWMC will continue to promote water quality monitoring efforts in Virginia by acting as a forum for citizen monitoring organizations; local and state government agencies; private businesses; and academic institutions to meet and work together. The VWMC will continue to provide information on upcoming water quality meetings and water quality monitoring activities in Virginia. The VWMC will also continue developing and maintaining the VWMC online inventory database of water monitoring programs and Geographic Information System (GIS) mapping application.

### **Implementation**

We recognize that each partner has a unique and specific organizational mission, responsibility, and need for water quality monitoring data. To ensure success of this partnership agreement, we agree to meet at least twice a year to coordinate efforts; outline tasks to meet shared goals; and evaluate progress towards those goals.

This Agreement reflects the partners' plan for cooperation and is not to be construed as a binding contract. Any party may leave this cooperative program at any time and for any reason and may enter into similar agreements with other organizations. This agreement will continue for a period of four years, at which time it will be updated and renewed upon mutual agreement of the partners.

Nothing in this agreement prohibits the partners from implementing other programs for which they are responsible. Additional parties may be added to this agreement upon the mutual consent of the partners.

We hereby agree to work together to promote and sustain citizen water quality monitoring in the Commonwealth of Virginia as described by this 2006 Letter of Agreement:

---

The Honorable L. Preston Bryant, Jr.  
Virginia Secretary of Natural Resources

---

(date)

---

David B. Bancroft, President  
Alliance for the Chesapeake Bay, Inc.

---

(date)

---

Stacey Brown, Virginia Save Our Streams  
Izaak Walton League of America

---

(date)

---

Cathy Bolton, President, Virginia Division  
Izaak Walton League of America

---

(date)

---

Joseph H. Maroon, Director  
Virginia Department of Conservation and Recreation

---

(date)

---

David Paylor, Director  
Virginia Department of Environmental Quality

---

(date)

---

Wayne Kirkpatrick, Chairman  
Virginia Citizens for Water Quality

---

(date)

---

Charles A. Frederickson, Chairman,  
Virginia Water Monitoring Council

---

(date)

## **Appendix 3**

### **Legislation Establishing the Virginia Citizen Water Quality Monitoring Program in the *Code of Virginia***

## **Legislation Establishing the Virginia Citizen Water Quality Monitoring Program in the *Code of Virginia***

### **HB497 and HB1859 Text as Enacted by the General Assembly of Virginia**

#### *Code of Virginia § 62.1-44.19:11. Citizen water quality monitoring program*

- A. *The Department of Environmental Quality shall establish a citizen water quality monitoring program to provide technical assistance and may provide grants to support citizen water quality monitoring groups if (i) the monitoring is done pursuant to a memorandum of agreement with the Department, (ii) the project or activity is consistent with the Department of Environmental Quality's water quality monitoring program, (iii) the monitoring is conducted in a manner consistent with the Virginia Citizens Monitoring Methods Manual, and (iv) the location of the water quality monitoring activity is part of the water quality control plan required under § 62.1-44.19:5. The results of such citizen monitoring shall not be used as evidence in any enforcement action.*
- B. *It shall be the goal of the Department to encourage citizen water quality monitoring so that 3,000 stream miles are monitored by volunteer citizens by 2010.*

## **Appendix 4**

# **Template for Submittal of Citizen Monitoring Data to the Virginia Department of Environmental Quality**

## **Instructions for Submittal of Citizen Monitoring Data to the Virginia Department of Environmental Quality (DEQ) Citizen Volunteer Database**

The Virginia Department of Environmental Quality (DEQ) offers an online database to store and retrieve citizen volunteer data. This service is provided free to citizen volunteers and other water quality monitors who submit data to DEQ. The website is accessible through the DEQ citizen monitoring website (<http://www.deq.virginia.gov/cmonitor>).

This database service will offer the general public and unregistered users the following features:

1. Provides a secure location to store data
2. Allows members and the public to view and download monitoring data.
3. Download monitoring data into spreadsheet compatible format.
4. Search monitoring data by group, county, watershed, or DEQ regional office
5. Online mapping feature displays monitoring sites
6. Easy to use charts and graphs to display monitoring data according to parameter and date
7. Download files such as QAPP templates and calibration log sheets

Users who register with DEQ to post data on the site will have all of the capabilities mentioned above including the following\*:

1. Provide a secure location to upload data. Only users registered to a volunteer account may add, delete, or edit event data or sample sites.
2. Upload files for users to downloads such as site photos and sample methods
3. Provide a forum to ask questions to other registered users

\* To simplify the database and ensure quality assurance, most large umbrella organizations (Friends of Shenandoah River, Save Our Streams) already have an account on the database. If a member group submits data to one or more of these large organizations, DEQ requests member groups to not register on the database. Monitoring data will appear on the database when the larger organization updates the database.

To use or upload to the DEQ database, a help file is available under the **Download** option found on the left hand side of the website. For groups who wish to submit data to DEQ through the database, below is a short list of requested data along with a general template.

1. All data should be in an Excel spreadsheet or compatible format.
2. All data should be included in one worksheet. Each monitoring event should be entered in a separate line of the data file.
3. Groups who register on the website must provide information to the DEQ database administrator regarding monitoring stations and which monitoring parameters are used.
4. After registering on the website, a spreadsheet containing the parameters along with some additional fields will be sent to the group. Instructions on how to submit the data will be provided.

To set up sample stations on the database, the following information is required.

1. Major Watershed: Indicate the major river basin where the site is located. Use the following major river basin identifications: (1) Shenandoah/Potomac, (2) James, (3) Rappahannock, (4) Roanoke, (5) Chowan River/Dismal Swamp, (6) Tennessee/Big Sandy, (7) Chesapeake Bay and Small Coastal Basins, (8) York, and (9) New.
2. Stream Name: Indicate the name of the stream that the station is actually located on, as identified from a USGS topographic map or other standard reference. If the site is on an unnamed tributary to a named stream, please state “(insert name of stream)- Unnamed tributary”.
3. Station Number: This number should be unique for each station monitored by a specific citizen or citizens’ group. The station number for a station should not change from one sampling event or data submittal to another.
4. DEQ ID Number: This number will be assigned by DEQ. Once a DEQ ID Number is assigned for a station, it should be included in all subsequent data submittals to DEQ to facilitate data use by the agency.
5. Station Location Description: Include a detailed station location description, so the station can be located on a map (*e.g.*, Rt. 619 bridge or 0.5 miles downstream of Rt. 619 bridge).
6. Latitude/Longitude: The database reports station latitude/longitude using decimal degrees. (ex. 38.441, -78.0011). If your station is recorded using degrees/ minutes/seconds (38o 41’ 34”, -78o 22’ 15”) or in another format, it must be converted to decimal degrees. A free online tool to convert coordinates is available at <http://www.topozone.com>
7. County: Indicate the county where the station is located.

**Citizen Monitoring Site Metadata Submittal Template**

Major River Basin	Stream Name	Station #	DEQ Station ID	Station Location Description	Latitude Decimal Degrees	Longitude Decimal Degrees	County
-------------------	-------------	-----------	----------------	------------------------------	--------------------------------	---------------------------------	--------

## **Appendix 5**

# **Boilerplate Memorandum of Agreement**

## **Memorandum of Agreement to Support the Virginia Citizen Water Quality Monitoring Program Between the Virginia Department Of Environmental Quality and ORGANIZATION NAME**

### **A. Purpose**

The Virginia Department of Environmental Quality (DEQ) and ORGANIZATION NAME are dedicated to supporting the Virginia Citizen Water Quality Monitoring Program for the purpose of collecting useful water quality information and encouraging environmental stewardship. We recognize that cooperative efforts enhance Virginia's ability to monitor, assess, protect and restore the Commonwealth's water quality while also strengthening citizen commitments to water quality issues. We have entered into this agreement with the understanding that combined efforts will produce greater and more consistent benefits by more effectively utilizing the resources of the DEQ and ORGANIZATION NAME and eliminating duplication of effort.

### **B. Background**

In the 2002 General Assembly Session, legislation was introduced and passed (§62.1-44.19:11 of the Code of Virginia) which gave DEQ the authority to provide grants to support citizen water quality monitoring groups if (i) the monitoring is done pursuant to a memorandum of agreement with the Department, (ii) the project or activity is consistent with the Department of Environmental Quality's water quality monitoring program, (iii) the monitoring is conducted in a manner consistent with the Virginia Citizens Monitoring Methods Manual, and (iv) the location of the water quality monitoring activity is part of the water quality control plan required under the Code of Virginia. This legislation also prohibits the use of citizen data as evidence in any enforcement actions.

[Customize the paragraph below for the organization]

ORGANIZATION NAME has been committed to protecting the natural resources of STREAM NAME OR WATERSHED NAME. ORGANIZATION NAME has collected water quality data over the past NUMBER years. In keeping with this commitment to protecting the natural resources of the STREAM NAME OR WATERSHED NAME, ORGANIZATION NAME is entering into this agreement with DEQ.

### **C. Signatory Responsibilities**

#### **Virginia Department of Environmental Quality**

Since a goal of the Virginia Citizen Water Quality Monitoring Program is to produce citizen water quality data that can be used by DEQ for water quality assessments, DEQ will provide technical expertise to assist ORGANIZATION NAME in meeting this goal. DEQ will continue to provide technical expertise and general information about monitoring water quality including monitoring protocols, planning water quality monitoring programs, existing agency monitoring locations, site selection, data management, and quality assurance and quality control measures. DEQ will maintain a Virginia citizen monitoring methods manual. DEQ will promote the use of

citizen water quality data to meet the Commonwealth's water quality data needs and will assist in identifying appropriate uses for citizen data. DEQ will continue to assist in identifying new opportunities for citizen stewardship efforts. As part of DEQ's statewide responsibilities, DEQ will provide technical expertise and general information on matters concerning point source pollution and Total Maximum Daily Load development.

ORGANIZATION NAME [Customize the paragraph below for the organization]

ORGANIZATION NAME will adhere to the Quality Assurance Project Plan developed by ORGANIZATION NAME and provide citizen water quality data for the watershed that can be used by DEQ for water quality assessments. ORGANIZATION NAME will be responsible for ensuring that their citizen monitors are properly trained, providing quality assurance oversight for participating volunteers, recruiting volunteers as necessary, and identifying new opportunities for citizen stewardship activities. ORGANIZATION NAME will use the water quality data collected for educational purposes and to assist with local land use decisions

**D. Monitoring Objectives** [Customize the paragraph below for the organization]

We recognize that cooperative efforts enhance Virginia's ability to monitor, assess, protect and restore the Commonwealth's water resources. To reduce duplication of efforts and to produce data that will be useful for water quality assessments, ORGANIZATION NAME will collect data that is consistent with DEQ's water quality monitoring programs. We recognize the need to coordinate water quality monitoring efforts in a collaborative effort to increase the quality and efficiency

**E. Quality Assurance Project Plans** [Customize the paragraph below for the organization]

The protocols used by ORGANIZATION NAME will be consistent with a revised Virginia citizen monitoring methods manual. ORGANIZATION NAME will select protocols appropriate for the goals of the program with DEQ's assistance. A Quality Assurance Project Plan, developed by ORGANIZATION NAME, documenting the procedures that ORGANIZATION NAME will use for water quality monitoring will be submitted by the end of the first year of this agreement for approval by DEQ.

**F. Monitoring Locations** [Customize the paragraph below for the organization]

We agree to share monitoring locations in an effort to reduce duplication of efforts and produce data that will be useful for water quality assessments. ORGANIZATION NAME should also consult the Virginia Water Monitoring Council website at <http://www.vwrrc.vt.edu/vwmc> for information on other water quality monitoring activities in the watershed.

### **G. Period of Performance**

The Virginia Citizen Water Quality Monitoring Program continues to evolve to meet the needs of the Commonwealth. This document reflects the signatories' plan for cooperative efforts and should not be construed as a binding contract. Either party may leave this cooperative program at any time and for any reason. Performance of this agreement will continue for a period of 24 months, at which time the agreement will be reviewed and renewed, upon mutual agreement of the signatories.

Nothing in this agreement prohibits DEQ, or ORGANIZATION NAME from entering into similar agreements with other organizations. Nothing in this agreement prohibits DEQ or ORGANIZATION NAME from implementing other programs for which they are responsible. Additional parties may be added to this agreement upon the mutual consent of the signatories.

### **H. Grant Agreement**

If ORGANIZATION NAME receives any sources of funding through the Commonwealth, a separate grant agreement with a workplan containing deliverables will be executed.

We, hereby, agree to the conditions described herein:

**ORGANIZATION NAME**

By:

\_\_\_\_\_

Title:

Date:  
\_\_\_\_\_

**Virginia Department of Environmental  
Quality**

By:

\_\_\_\_\_

Title: David K. Paylor, Director, Virginia  
Department of Environmental Quality

Date:

\_\_\_\_\_

## **Appendix 6**

### **Virginia Citizens for Water Quality List Serve**

### **Sign up for the VCWQ E-Mail List Serve**

**What is a List Serve?** A list serve is an e-mail message distribution list. You have to register your e-mail address to be included in the distribution list (this is called subscribing) and you send messages (called posting) to the central address for the e-mail distribution list. You can only post messages on the list-serve if you have subscribed!

**What is the purpose of the Virginia CWQ List Serve?** To provide a forum for open exchange of information, announcements, thoughts, and ideas about water quality issues in Virginia. Aside from the Virginia CWQ webpage, the list serve will be the only source of information about events – the list serve will serve as our e-mail distribution list!

**How do I join the Virginia CWQ List Serve?** The instructions are list below:

1. Go to the following website: <http://listadmin.vasos.org/mailman/listinfo/cwq>. There will also be a link to this page from the Virginia CWQ home page (<http://www.virginiacwq.org>)
2. Scroll down the page until you see the heading “Subscribing to CWQ
3. Fill in the form and click the subscribe button
4. Once the form has been submitted, you will receive an e-mail regarding the subscription.

Follow the directions in this e-mail to complete your subscription

Please contact Stacey if you have questions – [stacey@vasos.org](mailto:stacey@vasos.org) or 804-615-5036

### **Put the Virginia CWQ List Serve to work!**

Share announcements of events, ideas for Virginia CWQ members, and other water quality information on the list serve. Please refrain from using this list serve to post jokes or chain mails.

**How do I post a message on the Virginia CWQ List Serve?** To post an email message on the CWQ List-Serve after you have signed up, send your message to the following address: [cwq@list.vasos.org](mailto:cwq@list.vasos.org). Messages posted to the CWQ List-Serve will be forwarded to all currently registered subscribers of the CWQ List-Serve.

**How do I respond to a message on the Virginia CWQ List Serve?** To reply to a message posted on the CWQ List-Serve use the "Reply to:" or "Answer" feature of your email program to send a message to the originator of the message. If you would like your reply to go to the entire list serve, include [cwq@list.vasos.org](mailto:cwq@list.vasos.org) in the reply address.

### **Web Archive of the Virginia CWQ List Serve...**

All discussions that occur on the Virginia CWQ List Serve can be access via an archive online. This archive is located at <http://listadmin.vasos.org/mailman/listinfo/cwq>  
A link to the archive will also be made available on <http://www.virginiacwq.org>.

### **Virginia CWQ List Serve Options...**

Once you are subscribed, you can edit your user options by visiting the main page of the list (<http://listadmin.vasos.org/mailman/listinfo/cwq>). This is where you can unsubscribe, temporarily unsubscribe (if you are going on vacation), or change your digest options.

**Disclaimer and Legal Rules (the fine print!)**

This service is provided by Virginia Citizens for Water Quality (VCWQ) in cooperation with the Virginia Save Our Streams Program. VCWQ disclaims all warranties with regard to information posted on this site, whether posted by VCWQ or any third party. Do not post any defamatory, abusive, profane, threatening, offensive, or illegal materials. Do not post any information or other material protected by copyright without the permission of the copyright owner. VCWQ does not actively monitor the site for inappropriate postings and does not on its own undertake editorial control of postings. However, in the event that any inappropriate posting is brought to VCWQ's attention, VCWQ will take all appropriate action.

# **Appendix 7**

## **Resources**

## Resources

### **General Citizen Water Quality Monitoring Resources**

- Campbell, G. and S. Wildberger. 1992. *The Monitor's Handbook*. LaMotte Company, Chestertown, Md. 71 pp.
- Center for Marine Conservation & U. S. EPA. *Volunteer Estuary Monitoring: A Methods Manual*, Second Edition. Web site: <http://www.epa.gov/owow/monitoring/volunteer>
- Hach. 1997. *Hach Water Analysis Handbook*. 3<sup>rd</sup> ed. Hach Company, Loveland CO.
- Miller, J.K. 1995. *Program Organizing Guide*. River Watch Program of River Network. Montpelier, VT.
- Mitchell, M., and W. Stapp. 1999 *Field Manual for Water Quality Monitoring*. 12<sup>th</sup> ed. Kendall/Hunt. Available from GREEN, c/o Earth Force, Inc., 1908 Mount Vernon Ave., Alexandria, VA. Web site: <http://www.earthforce.org/green/>
- U. S. Environmental Protection Agency (USEPA). 1990. *Volunteer Water Monitoring: A Guide For State Managers*. EPA 440/4-90-010. August. Office of Water, Washington, DC. 78 pp. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>
- U. S. Environmental Protection Agency (USEPA), 1991. *Volunteer Lake Monitoring: A Methods Manual*. EPA 4400/4-91-002. Office of Water, Washington, DC. 121 pp. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>
- U. S. Environmental Protection Agency (USEPA). 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA841-B-97-003. November. Office of Water, Washington, DC. 211 pp. Web site: <http://www.epa.gov/owow/monitoring/volunteer/>

### **Web Sites**

- Chesapeake Bay Program: <http://www.chesapeakebay.net/>
- Virginia Citizens for Water Quality: <http://www.virginiacwq.org>
- National Oceanic & Atmospheric Administration (NOAA)
- National Sea Grant Program: <http://www.nsgo.seagrant.org/index.html>
- Volunteering for the Coast: <http://volunteer.nos.noaa.gov>
- U. S. Environmental Protection Agency (EPA)
- Surf Your Watershed: <http://www.epa.gov/surf>
- Volunteer Monitoring <http://www.epa.gov/owow/monitoring/volunteer/>
- Watershed Information Network <http://www.epa.gov/win>

Virginia Department of Conservation and Recreation (DCR)

Adopt-A-Stream: [http://www.dcr.virginia.gov/soil\\_&\\_water/adopt.shtml](http://www.dcr.virginia.gov/soil_&_water/adopt.shtml)

Virginia Department of Environmental Quality (DEQ)

Citizen Monitoring: <http://www.deq.virginia.gov/cmonitor>

DEQ Monitoring Data: [http://gisweb.deq.virginia.gov/monapp/mon\\_data\\_retrieval\\_app.html](http://gisweb.deq.virginia.gov/monapp/mon_data_retrieval_app.html)

Virginia Water Monitoring Council: <http://www.vwrrc.vt.edu/vwmc>

### **Newsletters**

*Coastlines* - National Estuary Program Newsletter

Available online at <http://www.epa.gov/nep/coastlines>. Subscriptions are free. To subscribe, contact [coastlines@umbsky.cc.umb.edu](mailto:coastlines@umbsky.cc.umb.edu)

*The Volunteer Monitor* - National Newsletter of Volunteer Water Quality Monitoring

Available online at [http://www.epa.gov/owow/monitoring/volunteer/vm\\_index.html](http://www.epa.gov/owow/monitoring/volunteer/vm_index.html)

Subscriptions are free. To subscribe, contact [skvigil@yahoo.com](mailto:skvigil@yahoo.com)

### **List Serves**

Citizens for Water Quality List Serve (Virginia Citizen Monitoring List Serve): Please see Appendix 6 for instructions and guidelines for this list serve.

EPA Volunteer Monitoring List Serve (National Citizen Monitoring List Serve):

To subscribe or unsubscribe, send an email to [listserv@unixmail.rtpnc.epa.gov](mailto:listserv@unixmail.rtpnc.epa.gov). Leave the subject line blank. In the message type:

Subscribe volmonitor lastname firstname or unsubscribe volmonitor lastname firstname

To post a message, address your email to [volmonitor@unixmail.rtpnc.epa.gov](mailto:volmonitor@unixmail.rtpnc.epa.gov).

## **Chapter 2: Quality Assurance Project Plans and Approved Methods**

American Public Health Association (APHA), American Water Works Association, and Water Environment Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20<sup>th</sup> ed. L. S. Clesceri, A. E. Greenberg, A.D. Eaton (eds). Washington, DC.

Mattson, M. 1992. "The Basics of Quality Control." *The Volunteer Monitor* 4(2): 6-8.

U. S. Environmental Protection Agency (USEPA). 1996. *The Volunteer Monitor's Guide to Quality Assurance Project Plans*. EPA 841-B-96-003. September. Web site: <http://www.epa.gov/OWOW/monitoring/volunteer/qappcovr.htm>

## **Chapter 4: Dissolved Oxygen**

Green, L. 1997. "Common Questions About DO Testing." *The Volunteer Monitor* 9(1).

Green, L. 1998. "Let Us Go Down to the Sea-How Monitoring Changes from River to Estuary." *The Volunteer Monitor* 10(2): 1-3.

## **Chapter 6: Nutrients**

Dates, G. 1994. "Monitoring for Phosphorus or How Come They Don't Tell You This Stuff in the Manual?" *The Volunteer Monitor* 6(1).

Katznelson, R. 1997. "Nutrient Test Kits: What Can We Expect?" *The Volunteer Monitor* 9(1).

## **Chapter 7: Benthic Macroinvertebrates**

Engel, Sarah R. and J. Reese Voshell, Jr. 2002. "Volunteer Biological Monitoring: Can It Accurately Assess the Ecological Condition of Streams?" *American Entomologist* 48 (3): 164-177. Web site: <http://www.vasos.org/ValidationStudy.htm>

U. S. Environmental Protection Agency (USEPA). 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers; Periphyton, Benthic Macroinvertebrates and Fish*, second edition, EPA Publication 841-B-99-002. Web site: <http://www.epa.gov/owow/monitoring/rbp>

## **Web Sites**

Virginia Save Our Streams Program: <http://www.vasos.org>

## **Chapter 8: Bacteria**

Ely, E. 1998. "Bacteria Testing Part 1: Methods Primer." *The Volunteer Monitor* 10(2):8-9

Ely, E. 1998. "Bacteria Testing Part 2: What Methods Do Volunteer Group Use?" *The Volunteer Monitor* 10(2): 10-13.

Ely, E. 1997 "Interpreting Fecal Coliform Data: Tracking Down the Right Sources." *The Volunteer Monitor* 9(2): 18-20

Miceli, G. 1998. "Bacteria Testing Q & A." *The Volunteer Monitor* 10(2): 13-15

## **Chapter 10: Submerged Aquatic Vegetation (SAV)**

U. S. Environmental Protection Agency (USEPA). 2000. *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis*. August.

Bergstrom, P. 1998. "SAV Hunter's Guide (for Chesapeake Bay)." *The Volunteer Monitor* 10(2): 17.

Hurley, L. M. 1992. *Field Guide to the Submerged Aquatic Vegetation of the Chesapeake Bay*. U. S. Fish and Wildlife Service Chesapeake Bay Estuary Program. Annapolis, MD. 52PP. (NOTE: Out of print).

Meyers, D. 1999. "Volunteers Add 'Missing Piece': Monitoring Restoration." *The Volunteer Monitor* 11(1): 10-11.

Reshetiloff, K. 1998 "SAV Hunt: Citizens Keep Track of Bay Grasses." *The Volunteer Monitor* 10(2): 16

### **Web Sites**

Alliance for the Chesapeake Bay: <http://www.acb-online.org/projects.cfm>

Chesapeake Bay Foundation: <http://www.savethebay.cbf.org>

Chesapeake Bay Program: <http://www.chesapeakebay.net/baygras.htm>

U. S. Fish and Wildlife Service Chesapeake Bay Field Office:  
<http://www.fws.gov/chesapeakebay/>

Virginia Institute of Marine Science: <http://www.vims.edu/bio/sav/index.html>

## **Chapter 15: Stream Flow**

Rantz, S.E., and others, 1982, *Measurement and Computation of Streamflow: Volume 2. Computation of Discharge*. U. S. Geological Survey Water-Supply Paper. 2175.

### **Web Sites**

U. S. Geological Survey (USGS): <http://www-vi.usgs.gov>

## **Chapter 16: Stream Walks**

U. S. Department of Agriculture. 1998. *National Water and Climate Center Technical Note 99-1: Stream Visual Assessment Protocol*. December.

U. S. Environmental Protection Agency (USEPA). 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA841-B-97-003. November. Office of Water, Washington, DC. 211 pp. Web site <http://www.epa.gov/owow/monitoring/volunteer/>

## **Chapter 17: Riparian Forests**

Austin, Samuel H. 1999. *Riparian Forest Handbook 1*, Virginia Department of Forestry, December.

## **Appendix 8**

### **Equipment Suppliers**

## Equipment Suppliers

This is a partial list of common equipment suppliers from which a volunteer monitoring program may obtain equipment for water quality monitoring. This list is intended to assist programs in locating equipment and does not imply endorsement by the Virginia Citizen Water Quality Monitoring Program or any of its partners.

### **Ben Meadows Company**

<http://www.benmeadows.com>

Phone: 800-241-6401

Waders, field water test equipment, nets.

### **Carolina Biological Supply Company**

<http://www.carolina.com>

Phone: 800-334-5551

Forceps, reagents, educational materials.

### **Cole Parmer Instruments, Inc.**

<http://www.coleparmer.com>

Phone: 800-323-4340

Lab equipment, field water test equipment.

### **Earth Force**

<http://www.earthforce.org>

E-mail: [green@earthforce.org](mailto:green@earthforce.org)

Phone: 703-299-9485

Low-cost kits for schools.

### **Fisher Scientific Company**

<http://www.fishersci.com>

Phone: 800-766-7000

Lab equipment, sample bottles, reagents, water test equipment, Whirl-paks.

### **Forestry Suppliers, Inc.**

<http://www.forestry-suppliers.com>

Phone: 800-647-5368

Secchi disks, transparency tubes, equipment.

### **HACH Equipment Company**

<http://www.hach.com>

Phone: 800-227-4224

Field and lab equipment, reagents.

### **Hydrolab Corporation**

<http://www.hydrolab.com>

Phone: 800-949-3766

Multi-parameter meters for water monitoring.

### **Idexx Laboratories**

<http://www.idexx.com/water>

Phone: 800-321-0207

Colilert method for bacterial monitoring.

### **LaMotte**

<http://www.lamotte.com>

Phone: 800-344-3100

Field and lab water testing equipment, Secchi disks, armored thermometers.

### **Micrology Laboratories**

<http://micrologylabs.com>

Phone: 888-EASYGEL

Coliscan Easygel method for bacterial monitoring.

### **Nichols Net and Twine, Inc.**

Phone: 618-797-0222; 800-878-6387

Nets of all kinds (dip, kick, macroinvertebrates), seines, custom nets.

### **Water Monitoring Equipment & Supply**

<http://www.watermonitoringequip.com>

E-mail: [info@watermonitoringequip.com](mailto:info@watermonitoringequip.com)

Phone: 207-276-5746

Transparency tubes, monitoring equipment.

### **YSI Incorporated**

<http://www.ysi.com>

Phone: 937-767-7241

Meters for water quality monitoring.

## **Appendix 9**

### **Levels of Quality Assurance and Uses of Citizen Water Quality Data by DEQ**

## Levels of Citizen Water Quality Data in Virginia

In Virginia, the Department of Environmental Quality (DEQ) has developed three levels of data quality for citizen and other non-DEQ water quality monitoring data based upon both the level of data quality and the authorized uses of the data provided to the agency. In addition to agency needs, citizen-collected data may also be used to educate the community, to assist local governments in land use planning, to supplement data for university and professional studies, and to assist local soil and water conservation districts in prioritizing watershed work for best management practices.

<b><u>Level</u></b>	<b><u>Appropriate Data Uses</u> (refer to Appendix 2 )</b>	<b><u>QA/QC Protocols</u></b>
III	<ul style="list-style-type: none"> <li>• List or delist waters on the 303(d) Impaired waters list</li> <li>• Assesses waters for 305(b) Report</li> <li>• Use with DEQ data for TMDL development</li> <li>• All uses listed in Levels I and II</li> </ul>	<ul style="list-style-type: none"> <li>• DEQ-approved Quality Assurance Project Plan and field or lab SOPs.</li> <li>• Field and/or laboratory audit required.</li> <li>• Group provides calibration and quality control associated information to DEQ when submitting data. This information must meet the specific criteria stated in the QAPP.</li> </ul>
II	<ul style="list-style-type: none"> <li>• Identify waters for DEQ follow up monitoring</li> <li>• Track performance of TMDL implementation</li> <li>• All uses listed in Level I</li> </ul>	<ul style="list-style-type: none"> <li>• DEQ-approved Quality Assurance Project Plan and disproved field or lab SOPs</li> <li>• At this level, there may be deviation from an approved method if it can be demonstrated that the method collects data of similar quality to an approved method.</li> </ul>
I	<ul style="list-style-type: none"> <li>• Education</li> <li>• Baseline</li> <li>• Notification of Possible Pollution Events</li> <li>• Local Land Use Decisions</li> <li>• Special Studies</li> </ul>	<ul style="list-style-type: none"> <li>• No Quality Assurance Project Plan (QAPP) or SOP required by DEQ.</li> <li>• Uniform methodology recommended.</li> <li>• QAPP, SOPs and/or lab methods do not meet DEQ quality assurance/quality control requirements.</li> <li>• There is no Virginia Water Quality Standard for parameter the method measures.</li> </ul>

### ***How DEQ Uses Volunteer Data-***

Using the table above, DEQ identified five principal uses of citizen volunteer data by the agency. A Data Use Authorization Form was then developed and circulated so that citizen volunteer groups could specify how they would like the agency to use their water quality data. A detailed explanation of each of these five uses of data follows:

- 1. List and delist impaired waters on the 303(d) Impaired Waters List-** Level III volunteer data could be used to list or delist waters on the 303(d) Impaired Waters List that is submitted to EPA every two years. An impaired water is one that fails to meet Virginia Water Quality Standards (<http://www.deq.virginia.gov/wqs>).

DEQ reviews and approves data provided by volunteer groups as well as from other private and government organizations for agency use. DEQ would therefore take responsibility for any consequences that resulted from our uses of data, whether citizen data or our own. There is no known basis for the generators of such data to be faced with any legal liability unless the data submitted to DEQ were fraudulent.

- 2. Source identification for TMDL development for waters already listed as impaired-** Level III volunteer data can be used in conjunction with DEQ monitored data to identify sources of pollution for 303(d) listed waters to help develop a TMDL and/or TMDL Implementation Plan. In the case of benthic data, DEQ must perform chemical monitoring to identify the specific cause(s) of a degraded benthic population.

By providing data to DEQ, citizens can help the agency develop a TMDL plan that when implemented, will improve the health of the waterbody.

- 3. Track progress of a TMDL Implementation Plan and other restoration-** Level II or III data can be used in waterbodies that already have a TMDL Implementation Plan and have begun restoration efforts. Volunteer data can enhance data collected at DEQ stations by monitoring at additional sample locations or by tracking the effectiveness of Best Management practices (BMP).
- 4. Identify waters for future DEQ monitoring-** DEQ uses Level II and III data to identify waters for which there are insufficient data to determine water quality. This list of waterbodies is included in the 305(b)/303(d) Integrated Water Quality Assessment Report. These waterbodies are given either a high or low priority for DEQ follow up monitoring based on the data provided by volunteer groups. This list helps DEQ sets priorities for the establishment of new monitoring stations.
- 5. Educate land owners on the water quality impacts of land use activities-** Water quality data of Level I, II, III, can be used for educational purposes.



### Use Authorization Form for Water Quality Data

<b>Name of Group or Organization:</b>		<b>Date:</b>	
<b>Name of Submitter:</b>	<b>Role or Title</b> (QA officer, leader, etc.)		
<b>Type(s) of Monitoring Conducted by Organization?</b>	<input type="checkbox"/> <b>Chemical</b> (pH, dissolved oxygen nutrients, etc.)	<input type="checkbox"/> <b>Physical</b> (Temperature, stream flow, etc.)	<input type="checkbox"/> <b>Biological</b> (Macroinvertebrate, E. coli, etc.)
<b>Type of Organization</b>	<input type="checkbox"/> Citizen Volunteer	<input type="checkbox"/> Federal Agency	<input type="checkbox"/> State Agency
	<input type="checkbox"/> Business or Industry	<input type="checkbox"/> College or University	<input type="checkbox"/> Other (Name):

On behalf of the group identified above, we agree that the Virginia Department of Environmental Quality (DEQ) may use water quality monitoring data we generate per our selection(s) below. Our choice(s) will remain in effect unless or until our organization submits changes in the future.

#### Options for Uses of Your Data (may select more than one)

- ☐ **1. List and delist impaired waters on the 303(d) Impaired Waters List**  
Data recognized by DEQ as Level III can be used to list or delist water on the 303(d) impaired waters list. We understand that 303(d) listed waters do not meet minimum water quality standards in Virginia and a Total Maximum Daily Load (TMDL) may eventually be developed to improve water quality.
- ☐ **2. Source identification for TMDL development for waters already listed as impaired**  
Level III data can be used in conjunction with DEQ monitored data to identify sources of pollution for 303(d) listed waters for TMDL development. We understand that our data will not be used by itself, without water quality data collected by DEQ, wherever possible.
- ☐ **3. Track progress of a TMDL Implementation Plan and other restoration**  
Level II or III data can be used to track the progress of restoration in a TMDL waterbody including installed Best Management Practices or to identify areas where other restoration efforts are taking place.
- ☐ **4. Identify waters for future DEQ monitoring**  
Level II or III data can be used to identify a waterbody for follow-up monitoring by DEQ. We understand that DEQ may not be able to monitor at these locations and/or assess water quality for some period of time.
- ☐ **5. Educate land owners on the water quality impacts of land use activities**  
All levels of data can be used to help in educating the community about water quality and land use activities.

**Signature** (if submitting by mail or fax): \_\_\_\_\_

<b>Mail:</b>	VA DEQ James Beckley (11 <sup>th</sup> floor) P. O. Box 1105 Richmond, VA. 23219	<b>Fax:</b>	James Beckley VA DEQ (804) 698-4116	<b>E-mail:</b>	<a href="mailto:jebeckley@deq.virginia.gov">jebeckley@deq.virginia.gov</a>
--------------	---	-------------	---	----------------	--

# **Appendix 10**

## **Monitoring Plan Worksheets**

## Monitoring Plan Worksheets

(Chapter 1 will guide you with completing these worksheets)

Project Name:\_\_\_\_\_

Organization Name:\_\_\_\_\_

Contact Person for Project:\_\_\_\_\_

Phone Number for Contact:\_\_\_\_\_

Email Address for Contact: \_\_\_\_\_

Mailing Address for Contact: \_\_\_\_\_

Date Monitoring Plan Completed: \_\_\_\_\_

### Step 1: Problem Definition/Background

1. What waterbody(ies) do you want to monitor?\_\_\_\_\_

2. What monitoring/studies have been conducted in your waterbody of interest?\_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

3. Have you consulted the following sources to determine if monitoring data has been collected:

- |  |                          |
|--|--------------------------|
| a. DEQ Water Quality Monitoring Database at<br><a href="http://www.deq.state.va.us/water/monitoring.html">http://www.deq.state.va.us/water/monitoring.html</a> | <input type="checkbox"/> |
| b. VWMC online database at<br><a href="http://www.vwrrc.vt.edu/vwmc/Survey.asp">http://www.vwrrc.vt.edu/vwmc/Survey.asp</a>                                    | <input type="checkbox"/> |
| c. USGS  | <input type="checkbox"/> |
| Local governments  | <input type="checkbox"/> |
| Local soil and water conservation district   | <input type="checkbox"/> |
| College or universities  | <input type="checkbox"/> |
| Others?_____   | <input type="checkbox"/> |

Problem statement/issues affecting your watershed?\_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## Step 2: Why Are You Monitoring?

A. Overall goals:\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

B. Questions and information needed to address issues

<b><u>Questions/Issues to Address</u></b>	<b><u>Information Needed</u></b>

**Step 3: Intended Uses and Users of Data**

List data users and intended use of data. Consult with data users to determine the quality of data they need. For example, if data will be used for screening purposes only, you may not need to use approved methods or follow rigorous quality assurance/quality control checks on the data.

<u>Data User</u>	<u>Data Use</u>	<u>Level of Data Quality Needed</u>

**Step 4: Where Will You Monitor?**

- A. Are all sites in safe locations on public property or where landowner permission has been obtained?\_\_\_\_\_
- B. Are all sites representative of the stream (in the main flow of the stream away from discharge pipes)?\_\_\_\_\_
- C. At what depth will samples be collected?\_\_\_\_\_



**Steps 5 & 6: What Parameters/Conditions Will You Monitor?**

Sampling Methods and Analytical Methods Requirements

<b><u>Parameter</u></b>	<b><u>Field or Lab Analysis</u></b>	<b><u>Sampling Method (specify lab analysis method number or manufacturer and model # of test kit, meter, or other instrument)</u></b>	<b><u>Why Do You Want to Monitor this Parameter?</u></b>
Bacteria - <i>E. coli</i>			
Bacteria – Fecal Coliform			
Benthic Macroinvertebrates			
Chlorophyll <i>a</i>			
Conductivity			
Dissolved Oxygen			
Flow			
Nitrogen (Identify species)			
pH			
Phosphorus (Identify species)			
Salinity			
Total Solids (specify form)			
Turbidity/ Transparency			
Water Temperature			
Other			
Other			
Other			
Other			
Other			

## Step 8: When Will You Sample?

[illegible]

## Step 9: Data Management and Reports

- A. What will happen to data sheets once they are completed?\_\_\_\_\_
- \_\_\_\_\_
- B. What software program will used?\_\_\_\_\_
- \_\_\_\_\_
- C. Who will enter the data?\_\_\_\_\_
- D. Who will verify the accuracy of data entry?\_\_\_\_\_
- E. How will data be analyzed? \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- F. How will data be communicated to others? \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

## Step 10: Quality Assurance/Quality Control

- A. Training Requirements/Certification
1. Who will train volunteers?\_\_\_\_\_
  2. Describe initial training requirements.\_\_\_\_\_
  - \_\_\_\_\_
  3. Describe refresher training requirements.\_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
- B. Is a QAPP needed for intended use of data?\_\_\_\_\_

If so, these worksheets can be expanded into a formal QAPP (Chapter 2 and Appendix 14 )

## **Appendix 11**

**Technical Resource: Excerpt from  
EPA *Guidance Specifying  
Management Measures for Sources  
of Nonpoint Pollution in Coastal  
Waters***

In 1990, Congress enacted the Coastal Zone Act Reauthorization Amendments and included a new section titled ‘Protecting coastal waters (Section 6217)’. The program is jointly administered by the National Oceanic & Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA). The purpose of the program is to develop and implement management measures for nonpoint sources of pollution to restore and protect coastal waters. A key element of the program is to work in coordination with other federal, state, and local entities. Each state program is required to develop a program under this section that will ‘provide for the implementation, at a minimum, of management measures in conformity with the guidance published under subsection (g), to protect coastal waters.’

This appendix is intended to provide additional technical resource information to organizations and individuals that conduct water quality monitoring activities. The information has been excerpted from guidance developed by national work groups and released in 1993 by EPA. The full guidance document can be found at <http://www.epa.gov/owow/nps/MMGI>. EPA has recently released updated individual chapters as ‘national’ management measures. The updates can be found at <http://www.epa.gov/owow/nps/pubs.html>.

## **II. Techniques for Assessing Water Quality and for Estimating Pollution Loads**

Water quality monitoring is the most direct and defensible tool available to evaluate water quality and its response to management and other factors (Coffey and Smolen, 1990). This section describes monitoring methods that can be used to measure changes in pollutant loads and water quality. Due to the wide range of monitoring needs and environmental conditions throughout the coastal zone it is not possible to specify detailed monitoring plans that apply to all areas within the zone. The information in this section is intended merely to guide the development of monitoring efforts at the State and local levels.

This section begins with a brief discussion of the scope and nature of nonpoint source problems, followed by a discussion of monitoring objectives as they relate to section 6217. A lengthy discussion of monitoring approaches is next, with a focus on understanding the watershed to be studied, appropriate experimental designs, sample size and frequency, site locations, parameter selection, sampling methods, and quality assurance and quality control. The intent of this discussion is to provide the reader with basic information essential to the development of effective, tailored monitoring programs that will provide the necessary data for use in statistical tests that are appropriate for evaluating the success of management measures in reducing pollutant loads and improving water quality.

After a brief discussion of data needs, an overview of statistical considerations is presented. Variability and uncertainty are described first, followed by a lengthy overview of sampling and sampling designs. This discussion is at a greater level of detail than others in the section to emphasize the importance of adequate sampling within the framework of a sound experimental design. Hypothesis testing is described next, including some examples of hypotheses that may be appropriate for section 6217 monitoring efforts. An overview of data analysis techniques is given at the end of the section.

## **A. Nature and Scope of Nonpoint Source Problems**

Nonpoint sources may generate both conventional and toxic pollutants, just as point sources do. Although nonpoint sources may contribute many of the same kinds of pollutants, these pollutants are generated in different volumes, combinations, and concentrations. Pollutants from nonpoint sources are mobilized primarily during storm events or snowmelt, but baseflow contributions can be the major source of nonpoint source contaminants in some systems. Thus, knowledge of the hydrology of a system is critical to the design of successful monitoring programs.

Nonpoint source problems are not just reflected in the chemistry of a water resource. Instead, nonpoint source problems are often more acutely manifested in the biology and habitat of the aquatic system. Such impacts include the destruction of spawning areas, impairments to the habitat for shellfish, changes to aquatic community structure, and fish mortality. Thus, any given nonpoint source monitoring program may have to include a combination of chemical, physical, and biological components to be effective.

## **B. Monitoring Objectives**

Monitoring is usually performed in support of larger efforts such as nonpoint source pollution control programs within coastal watersheds. As such, monitoring objectives are generally established in a way that contributes toward achieving the broader program objectives. For example, program objectives may include restoring an impaired use or protecting or improving the ecological condition of a water resource. Supporting monitoring objectives, then, might include assessing trends in use support or in key biological parameters.

The following discussion identifies the overall monitoring objectives of section 6217 and gives some examples of specific objectives that may be developed at the State or local level in support of those overall objectives. Clearly, due to the prohibitive expense of monitoring the effectiveness of every management measure applied in the coastal zone, States will need to develop a strategy for using limited monitoring information to address the broad questions regarding the effectiveness of section 6217 implementation. A combination of watershed monitoring to track the cumulative benefits of systems of management measures and demonstrations of selected management measures of key importance in the State may be one way in which the overall section 6217 monitoring objectives can be met within the constraints imposed by limited State monitoring budgets.

### **1. Section 6217 Objectives**

The overall management objective of section 6217 is to develop and implement management measures for nonpoint source pollution to restore and protect coastal waters. The principal monitoring objective under section 6217(g) is to assess over time the success of the management measures in reducing pollution loads and improving water quality. A careful reading of this monitoring objective reveals that there are two sub-objectives: (1) to assess changes in pollution loads over time and (2) to assess changes in water quality over time.

A pollutant load is determined by multiplying the total runoff volume times the average concentration of the pollutant in the runoff. Loads are typically estimated only for chemical and some physical (e.g., total suspended solids) parameters. Water quality, however, is determined on the basis of the chemical, physical, and biological conditions of the water resource. Section 6217(g), therefore, calls for a description of pollutant load estimation techniques for chemical and physical parameters, plus a description of techniques to assess water quality on the basis of chemical, physical, and biological conditions. This section focuses on those needs.

## **2. Formulating Monitoring Objectives**

A monitoring objective should be narrowly and clearly defined to address a specific problem at an appropriate level of detail (Coffey and Smolen, 1990). Ideally, the monitoring objective specifies the primary parameter(s), location of monitoring (and perhaps the timing), the degree of causality or other relationship, and the anticipated result of the management action. The magnitude of the change may also be expressed in the objective. Example monitoring objectives include:

- To determine the change in trends in the total nitrogen concentration in Beautiful Sound due to the implementation of nutrient management on cropland in all tributary watersheds.
- To determine the sediment removal efficiency of an urban detention basin in New City.
- To evaluate the effects of improved marina management on metals loadings from the repair and maintenance areas of Stellar Marina.
- To assess the change in weekly mean total suspended solids concentrations due to forestry harvest activities in Clean River.

## **C. Monitoring Approaches**

### **1. General**

#### **a. Types of Monitoring**

The monitoring program design is the framework for sampling, data analysis, and the interpretation of results (Coffey and Smolen, 1990). MacDonald (1991) identifies seven types of monitoring:

1. Trend monitoring;
2. Baseline monitoring;
3. Implementation monitoring;
4. Effectiveness monitoring;
5. Project monitoring;
6. Validation monitoring; and
7. Compliance monitoring.

Trend, baseline, implementation, effectiveness, and project monitoring all relate to the monitoring objectives of section 6217. These types of monitoring, in fact, are not mutually exclusive. The distinction between effectiveness monitoring and project monitoring, for

example, is often simply one of scale, with effectiveness monitoring primarily directed at individual practices and project monitoring directed at entire sets of practices or activities implemented over a larger area. Since one cannot evaluate the effectiveness of a project or management measure (i.e., achievement of the desired effect) without knowing the status of implementation, implementation monitoring is an essential element of both project and effectiveness monitoring. In addition, a test for trend is typically included in the evaluation of projects and management measures, and baseline monitoring is performed prior to the implementation of pollution controls.

Meals (1991a) discussed five major points to consider in developing a monitoring system that would provide a suitable data base for watershed trend detection: (1) understand the system you want to monitor, (2) design the monitoring system to meet objectives, (3) pay attention to details at the beginning, (4) monitor source activities, and (5) build in feedback loops. These five points apply equally to both load estimation and water quality assessment monitoring efforts.

### **b. Section 6217 Monitoring Needs**

The basic monitoring objective for section 6217 is to assess over time the success of the measures in reducing pollution loads and improving water quality. This objective would seem to indicate a need for establishing cause-effect relationships between management measure implementation and water quality. Although desirable, monitoring to establish such cause-effect relationships is typically beyond the scope of affordable program monitoring activities.

Mosteller and Tukey (1977) identified four criteria that must be met to show cause and effect: association, consistency, responsiveness, and a mechanism.

- **Association** is shown by demonstrating a relationship between two parameters (e.g., a correlation between the extent of management measure implementation and the level of pollutant loading).
- **Consistency** can be confirmed by observation only and implies that the association holds in different populations (e.g., management measures were implemented in several areas and pollutant loading was reduced, depending on the effect of treatment, in each case).
- **Responsiveness** can be confirmed by an experiment and is shown when the dependent variable (e.g., pollutant loading) changes predictably in response to changes in the independent variable (e.g., extent of management measure implementation).
- **Mechanism** is a plausible step-by-step explanation of the statistical relationship. For example, conservation tillage reduced the edge-of-field losses of sediment, thereby removing a known fraction of pollutant source from the stream or lake. The result was decreased suspended sediment concentration in the water column.

Clearly, the cost of monitoring needed to establish cause-effect relationships throughout the coastal zone far exceeds available resources. It may be suitable, however, to document associations between management measure implementation and trends in pollutant loads or water quality and then account for such associations with a general description of the primary mechanisms that are believed to come into play.

### **c. Scale, Local Conditions, and Variability**

There are several approaches that can be taken to assess the effectiveness of measures in reducing loads and improving water quality. There are also several levels of scale that could be selected: individual practices, individual measures, field scale, watershed scale, basin scale, regional scale, etc. With any given monitoring objective, the specific monitoring approach to use at any specific site is a function of the local conditions (e.g., geography, climate, water resource type) and the type of management measures implemented.

The detection and estimation of trends is complicated by problems associated with the characteristics of pollution data (Gilbert, 1987). Physical, chemical, and biological parameters in the receiving water may undergo extreme changes without the influence of human activity. Understanding and monitoring the factors responsible for variability in a local system are essential for detecting the improvements expected from the implementation of management measures.

Simple point estimates taken before and after treatment will not confirm an effect if the natural variability is typically greater than the changes due to treatment (Coffey and Smolen, 1990). Therefore, knowledge of the variability and the distribution of the parameter is important for statistical testing. Greater variability requires a larger change to imply that the observed change is not due solely to random events (Spooner et al., 1987b). Examination of a historical data set can help to identify the magnitude of natural variability and possible sources.

The impact of management actions may not be detectable as a change in a mean value but rather as a change in variability (Coffey and Smolen, 1990). Platts and Nelson (1988) found that a carefully designed study was required to isolate the large natural fluctuations in trout populations to distinguish the effects of land use management. They assumed that normal fluctuation patterns were similar between the control and the treatment area and that treatment-induced effect could be distinguished as a deviation from the historical pattern.

Meals (1991a) calls for the collection and evaluation of existing data as the first step in a monitoring effort, recognizing that additional background data may be needed to identify hot spots or fill information gaps. The results of such initial efforts should include established stage-discharge ratings and an understanding of patterns not associated with the pollution control effort.

## **2. Understanding the System to Be Monitored**

### **a. The Water Resource**

Options for tracking water quality vary with the type of water resource. For example, a monitoring program for ephemeral streams can be different from that for perennial streams or large rivers. Lakes, wetlands, riparian zones, estuaries, and near-shore coastal waters all present different monitoring considerations. Whereas upstream-downstream designs work on rivers and streams, they are generally less effective on natural lakes where linear flow is not so prevalent.

Likewise, estuaries present difficulties in monitoring loads because of the shifting flows and changing salinity caused by the tides. A successful monitoring program recognizes the unique features of the water resources involved and is structured to either adapt to those features or avoid them.

**Streams.** Freshwater streams can be classified on the basis of flow attributes as intermittent or perennial streams. Intermittent streams do not flow at all times and serve as conveyance systems for runoff. Perennial streams always flow and usually have significant inputs from ground water or interflow. For intermittent streams, seasonal variability is a very significant factor in determining pollutant loads and water quality. During some periods sampling may be impossible due to no flow. Seasonal flow variability in perennial streams can be caused by seasonal patterns in precipitation or snowmelt, reservoir discharges, or irrigation practices.

For many streams the greatest concentrations of suspended sediment and other pollutants occur during spring runoff or snowmelt periods. Concentrations of both particulate and soluble chemical parameters have been shown to vary throughout the course of a rainfall event in many studies across the Nation. This short-term variability should be considered in developing monitoring programs for flowing (lotic) waterbodies.

Spatial variability is largely lateral for both intermittent and perennial streams. Vertical variability does exist, however, and can be very important in both stream types (e.g., during runoff events, in tidal waters, and in deep, slow-moving streams). Intake depth is often a key factor in stream sampling. For example, slow-moving, larger streams may show considerable water quality variability with depth, particularly for parameters such as suspended solids, dissolved oxygen, and algal productivity. Suspended sediment samples must be taken with an understanding of the vertical distribution of both sediment concentration and flow velocity (Brakensiek et al., 1979). When sampling bed sediment or monitoring biological parameters, it is important to recognize the potential for significant lateral and vertical variation in the toxicity and contaminant levels of bed sediments (USEPA, 1987).

**Lakes.** Lakes can be categorized in several ways, but a useful grouping for monitoring guidance is related to the extent of vertical and lateral mixing of the waterbody. Therefore, lakes are considered to be either mixed or stratified for the purpose of this guidance. Mixed lakes are those lakes in which water quality (as determined by measurement of the parameters and attributes of interest) is homogenous throughout, and stratified lakes are considered to be those lakes which have lateral or vertical water quality differentials in the lake parameters and attributes of interest. Totally mixed lakes, if they exist, are certainly few in number, but it may be useful to perform monitoring in selected homogenous portions of stratified lakes to simplify data interpretation. Similarly, for lakes that exhibit significant seasonal mixing, it may be beneficial to monitor during a time period in which they are mixed. For some monitoring objectives, however, it may be best to monitor during periods of peak stratification.

Temporal variability concerns are similar for mixed and stratified lakes. Seasonal changes are often obvious, but should not be assumed to be similar for all lakes or even the same for different parts of any individual lake. Due to the importance of factors such as precipitation characteristics, climate, lake basin morphology, and hydraulic retention characteristics, seasonal

variability should be at least qualitatively assessed before any lake monitoring program is initiated.

Short-term variability is also an inherent characteristic of most still (lentic) waterbodies. Parameters such as pH, dissolved oxygen, and temperature can vary considerably over the course of a day. Monitoring programs targeted toward biological parameters should be structured to account for this short-term variability. It is often the case that small lakes and reservoirs respond rapidly to runoff events. This factor can be very important in cases where lake water quality will be correlated to land treatment activities or stream water quality.

In stratified lakes spatial variability can be lateral or vertical. The classic stratified lake is one in which there is an epilimnion and a hypolimnion (Wetzel, 1975). Water quality can vary considerably between the two strata, so sampling depth is an important consideration when monitoring vertically stratified lakes.

Lateral variability is probably as common as vertical variability, particularly in lakes and ponds receiving inflow of varying quality. Figure 8-1 illustrates the types of factors that contribute to lateral variability in lake water quality. In reservoir systems, storm plumes can cause significant lateral variability.

Davenport and Kelly (1984) explained the lateral variability in chlorophyll a concentrations in an Illinois lake based on water depth and the time period that phytoplankters spend in the photic zone. A horizontal gradient of sediment, nutrient, and chlorophyll a concentrations in St. Albans Bay, Vermont, was related to mixing between Lake Champlain and the Bay (Clausen, 1985). It is important to note that there frequently exists significant lateral and vertical variation in the toxicity and contaminant levels of bed sediments (USEPA, 1987).

Despite the distinction made between mixed and stratified lakes, there is considerable gray area between these groups. For example, thermally stratified lakes may be assumed to be mixed during periods of overturn, and laterally stratified lakes can sometimes be treated as if the different lateral segments are sub-lakes. In any case, it is important that the monitoring team knows what parcel of water is being sampled when the program is implemented. It would be inappropriate, for example, to assign the attributes of a surface sample to the hypolimnion of a stratified lake due to the differences in temperature and other parameters between the upper and lower waters.

Estuaries. Estuaries can be very complex systems, particularly large ones such as the Chesapeake Bay. Estuaries exhibit temporal and spatial variability just as streams and lakes do. Physically, the major differences between estuaries and fresh waterbodies are related to the mixing of fresh water with salt water and the influence of tides. These factors increase the complexity of spatial and temporal variability within an estuary.

Short-term variability in estuaries is related directly to the tidal cycles, which can have an effect on both the mixing of the fresh and saline waters and the position of the freshwater-saltwater interface (USEPA, 1982a). The same considerations made for lakes regarding short-term variability of parameters such as temperature, dissolved oxygen, and pH should also be made for estuaries.

Temperature profiles such as those found in stratified lakes can also change with season in estuaries. The resulting circulation dynamics must be considered when developing monitoring programs. The effects of season on the quantity of freshwater runoff to an estuary can be profound. In the Chesapeake Bay, for example, salinity is generally lower in the spring and higher in the fall due to the changes in freshwater runoff from such sources as snowmelt runoff and rainfall (USEPA, 1982a).

Spatial variability in estuaries has both significant vertical and lateral components. The vertical variability is related to both temperature and chemical differentials. In the Chesapeake Bay thermal stratification occurs during the summer, and chemical stratification occurs at all times, but in different areas at different times (USEPA, 1982a). Chemical stratification can be the result of the saltwater wedge flowing into and under the freshwater outflow or the accumulation or channeling of freshwater and saltwater flows to opposite shores of the estuary. The latter situation can be caused by a combination of tributary location, the earth's rotation, and the barometric pressure. In addition, lateral variability in salinity can be caused by different levels of mixing between saltwater and freshwater inputs. As noted for streams and lakes, the lateral and vertical variation in the toxicity and contaminant levels of bed sediments should be considered (EPA, 1987).

**Coastal Waters.** Researchers and government agencies are collectively devoid of significant experience in evaluating the effectiveness of nonpoint source pollution control efforts through the monitoring of near-shore and offshore coastal waters. Our understanding of the factors to consider when performing such monitoring is therefore very limited.

As for other waterbody types, it is important to understand the hydrology, chemistry, and biology of the system in order to develop an effective monitoring program. Of particular importance is the ability to identify discrete populations to sample from. For trend analysis it is essential that the researcher is able to track over time the conditions of a clearly identifiable segment or unit of coastal water. This may be accomplished by monitoring a semi-enclosed near-shore embayment or similar system. Knowledge of salinity and circulation patterns should be useful in identifying such areas.

Secondly, monitoring should be focused on those segments or units of coastal water for which there is a reasonable likelihood that changes in water quality will result from the implementation of management measures. Segment size, circulation patterns, and freshwater inflows should be considered when estimating the chances for such water quality improvements.

Near-shore coastal waters may exhibit salinity gradients similar to those of estuaries due to the mixing of fresh water with salt water. Currents and circulation patterns can create temperature gradients as well. Farther from shore, salinity gradients are less likely, but gradients in temperature may occur. In addition, vertical gradients in temperature and light may be significant. These and other biological, chemical, and physical factors should be considered in the development of monitoring programs for coastal waters.

### 3. Experimental Design

#### a. Types of Experimental Designs

EPA has prescribed monitoring designs for use in watershed projects funded under section 319 of the Clean Water Act (USEPA, 1991b). The objective in promoting these designs is to document changes in water quality that can be related to the implementation of nonpoint source control measures in selected watersheds. The designs recommended by EPA are paired-watershed designs and upstream-downstream designs. Single downstream station designs are not recommended by EPA for section 319 watershed projects (USEPA, 1991b).

Monitoring before implementation is usually required to detect a trend or show causality (Coffey and Smolen, 1990). Two years of pre-implementation monitoring are typically needed to establish an adequate baseline. Less time may be needed for studies at the management measure or edge-of-field scale, when hydrologic variability is known to be less than that of typical agricultural systems, or when a paired-watershed design is used.

**Paired-Watershed Design.** In the paired-watershed design there is one watershed where the level of implementation (ideally) does not change (the control watershed) and a second watershed where implementation occurs (the study watershed). This design has been shown in agricultural nonpoint source studies to be the most powerful study design for demonstrating the effectiveness of nonpoint source control practice implementation (Spooner et al., 1985). Paired-watershed designs have a long history of application in forest hydrology studies. The paired-watershed design must be implemented properly, however, to generate useful data sets. Some of the considerations to be made in designing and implementing paired-watershed studies are described below.

In selecting watershed pairs, the watersheds should be as similar as possible in size, shape, aspect, slope, elevation, soil type, climate, and vegetative cover (Striffler, 1965). The general procedure for paired-watershed studies is to monitor the watersheds long enough to establish a statistical relationship between them. A correlation should be found between the values of the monitored parameters for the two watersheds. For example, the total nitrogen values in the control watershed should be correlated with the total nitrogen values in the study watershed. A pair of watersheds may be considered sufficiently calibrated when a parameter for the control watershed can be used to predict the corresponding value for the study watershed (or vice versa) within an acceptable margin of error.

It is important to note that the calibration period should cover all or the significant portion of the range of conditions for each of the major water quality determinants in the two watersheds. For example, the full range of hydrologic conditions should be covered (or nearly covered) during the calibration period. This may be problematic in areas where rainfall and snowmelt are highly variable from year to year or in areas subject to extended wet periods or drought. Calibration during a dry year is likely to not be adequate for establishing the relationship between the two watersheds, particularly if subsequent years include both wet and dry periods. Similarly, some agricultural areas of the country use long-term, multiple-crop rotations. The calibration period should cover not only the range of hydrologic conditions but also the range of cropping patterns that can reasonably be expected to have an influence on the measured water

quality parameters. This is not to say that the calibration period should take 5 to 10 years, but rather that States should use careful judgment in determining when the calibration period can be safely ended.

After calibration, the study watershed receives implementation of management measures, and monitoring is continued in both watersheds. The effects of the management measures are evaluated by testing for a change in the relationship between the monitored parameters (i.e., a change in the correlation). If treatment is working, then there should be a greater difference over time between the treated study watershed and the untreated (poorly managed) control watershed. Alternatively, the calibration period could be used to establish statistical relationships between a fully treated watershed (control watershed) and an untreated watershed (study watershed). After calibration under this approach, the study watershed would be treated and monitoring continued. The effects of the management measures would be evaluated, however, by testing for a change in the correlation that would indicate that the two watersheds are more similar than before treatment.

It is important to use small watersheds when performing paired-watershed studies since they are more easily managed and more likely to be uniform (Striffler, 1965). EPA recommends that paired watersheds be no larger than 5,000 acres (USEPA, 1991b).

**Upstream-Downstream Studies.** In the upstream-downstream design, there is one station at a point directly upstream from the area where implementation of management measures will occur and a second station directly downstream from that area. Upstream-downstream designs are generally more useful for documenting the magnitude of a nonpoint source than for documenting the effectiveness of nonpoint source control measures (Spooner et al., 1985), but they have been used successfully for the latter. This design provides for the opportunity to account for covariates (e.g., an upstream pollutant concentration that is correlated with a downstream concentration of same pollutant) in statistical analyses and is therefore the design that EPA recommends in cases where paired watersheds cannot be established (USEPA, 1991b).

Upstream-downstream designs are needed in cases where project areas are not located in headwaters or where upstream activities that are expected to confound the analysis of downstream data occur. For example, the effects of upstream point source discharges, uncontrolled nonpoint source discharges, and upstream flow regulation can be isolated with upstream-downstream designs.

**Inflow-Outflow Design.** Inflow-outflow, or process, designs are very similar to upstream-downstream designs. The major differences are scale and the significance of confounding activities. Process designs are generally applied in studies of individual management measures or practices. For example, sediment loading at the inflow and outflow of a detention basin may be measured to determine the pollutant removal efficiency of the basin. In general, no inputs other than the inflow are present, and the only factor affecting outflow is the management measure. As noted above (see The Management Measures to Be Implemented), process monitoring cannot generally be applied to studies of source-reduction management measures or measures that prevent direct impacts, but it can be applied successfully in the evaluation of delivery-reduction management measures.

## **b. Scale**

**Management Measure.** Monitoring the inflow and outflow of a specific management measure should be the most sensitive scale since the effects of uncontrollable discharges and uncertainties in treatment mechanisms are minimized.

**Edge of Field.** Monitoring pollutant load from a single-field watershed should be the next most sensitive scale since the direct effects of implementation can be detected without pollutant trapping in a field border or stream channel (Coffey and Smolen, 1990).

**Sub-watershed.** Monitoring a sub-watershed can be useful to monitor the aggregate effect of implementation on a group of fields or smaller areas by taking samples close to the treatment (Coffey and Smolen, 1990). Sub-watershed monitoring networks measure the aggregate effects of treatment and nontreatment runoff as it enters an upgradient tributary or the receiving waterbody. Sub-watershed monitoring can also be used for targeting critical areas.

**Watershed.** Monitoring at the watershed scale is appropriate for assessing total project area pollutant load using a single station (Coffey and Smolen, 1990). Depending on station arrangement, both sub-watershed and watershed outlet studies are very useful for water and pollutant budget determinations. Monitoring at the watershed outlet is the least sensitive of the spatial scales for detecting treatment effect. Sensitivity of the monitoring program decreases with increased basin size and decreased treatment extent or both (Coffey and Smolen, 1990).

## **c. Reference Systems and Standards**

EPA's rapid bioassessment protocols advocate an integrated assessment, comparing habitat and biological measures with empirically defined reference conditions (Plafkin et al., 1989). Reference conditions are established through systematic monitoring of actual sites that represent the natural range of variation in "least disturbed" water chemistry, habitat, and biological condition. Reference sites can be used in monitoring programs to establish reasonable expectations for biological, chemistry, and habitat conditions. An example application of this concept is the paired-watershed design (Coffey and Smolen, 1990).

EPA's ecoregional framework can be used to establish a logical basis for characterizing ranges of ecosystem conditions or quality that are realistically attainable (Omernik and Gallant, 1986). Ecoregions are defined by EPA to be regions of relative homogeneity in ecological systems or in relationships between organisms and their environments. Hughes et al. (1986) have used a relatively small number of minimally impacted regional reference sites to assess feasible but protective biological goals for an entire region.

Water quality standards can be used to identify criteria that serve as reference values for biological, chemical, or habitat parameters, depending on the content of the standard. The frequency distribution of observation values can be tracked against either a water quality standard criterion or a reference value as a method for measuring trends in water quality or loads (USEPA, 1991b).

#### **4. Site Locations**

Within any given budget, site location is a function of water resource type (see The Water Resource), monitoring objectives (see Monitoring Objectives), experimental design (see Types of Experimental Designs), the parameters to be monitored (see Parameter Selection), sampling techniques (see Sampling Techniques and Samples and Sampling), and data analysis plans (see Data Analysis). Additional considerations in site selection are accessibility and landowner cooperation.

It is recommended that monitoring stations be placed near established gauging stations whenever possible due to the extreme importance of obtaining accurate discharge measurements. Where gauging stations are not available but stream discharge measurements are needed, care should be taken to select a suitable site. Brakensiek et al. (1979) provide excellent guidance regarding runoff measurement, including the following selected recommendations regarding site selection:

- Field-calibrated gauging stations should be located in straight, uniform reaches of channel having smooth beds and banks of a permanent nature whenever possible.
- Gauging stations should be located away from sewage outfall, power stations, or other installations causing flow disturbances.
- Consider the geology and contributions of ground-water flow.
- Where ice is a potential problem, locate measuring devices in a protected area that receives sunlight most of the time.
- Daily current-meter measurements may be necessary where sand shifts occur.

#### **5. Sampling Frequency and Interval**

##### **a. Sample Size and Frequency**

It is important to estimate early in a monitoring effort the number and frequency of samples required to meet the monitoring objectives. Spooner et al. (1991) report that the sampling frequency required at a given monitoring station is a function of the following:

- Monitoring goals;
- Response of the water resource to changes in pollutant sources;
- Magnitude of the minimum amount of change for which detection with trend analyses is desired (i.e., minimum detectable change);
- System variability and accuracy of the sample estimate of reported statistical parameter (e.g., confidence interval width on a mean or trend estimate);
- Statistical power (i.e., probability of detecting a true trend);
- Autocorrelation (i.e., the extent to which data points taken over time are correlated);
- Monitoring record length;

- Number of monitoring stations; and
- Statistical methods used to analyze the data.

The minimum detectable change (MDC) is the minimum change in a water quality parameter over time that is considered statistically significant. Knowledge of the MDC can be very useful in the planning of an effective monitoring program (Coffey and Smolen, 1990). The MDC can be estimated from historical records to aid in determining the required sampling frequency and to evaluate monitoring feasibility (Spoonier et al., 1987a). MacDonald (1991) discusses the same concept, referring to it as the minimum detectable effect.

The larger the MDC, the greater the change in water quality that is needed to ensure that the change was not just a random fluctuation. The MDC may be reduced by accounting for covariates, increasing the number of samples per year, and increasing the number of years of monitoring. Sherwani and Moreau (1975) stated that the desired frequency of sampling is a function of several considerations associated with the system to be studied, including:

- Response time of the system;
- Expected variability of the parameter;
- Half-life and response time of constituents;
- Seasonal fluctuation and random effects;
- Representativeness under different conditions of flow;
- Short-term pollution events;
- Magnitude of response; and
- Variability of the inputs.

Coastal waters, estuaries, ground water, and lakes will typically have longer response times than streams and rivers. Thus, sampling frequency will usually be greater for streams and rivers than for other water resource types. Some parameters such as total suspended solids and fecal coliform bacteria can be highly variable in stream systems dominated by nonpoint sources, while nitrate levels may be less volatile in systems driven by baseflow from ground water. The highly variable parameters would generally require more frequent sampling, but parameter variability should be evaluated on a site-specific basis rather than by rule of thumb.

In cases where pollution events are relatively brief, sampling periods may also be short. For example, to determine pollutant loads it may be necessary to sample frequently during a few major storm events and infrequently during baseflow conditions. Some parameters vary considerably with season, particularly in watersheds impacted primarily by nonpoint sources. Boating is typically a seasonal activity in northern climates, so intensive seasonal monitoring may be needed to evaluate the effectiveness of management measures for marinas.

The water quality response to implementation of management measures will vary considerably across the coastal zone. Pollutant loads from confined livestock operations may decline significantly in response to major improvements in runoff and nutrient management, while

sediment delivery from logging areas may decline only a little if the level of pollution control prior to section 6217 implementation was already fairly good. Fewer samples will usually be needed to document water quality improvement in watersheds that are more responsive to pollution control efforts.

Sherwani and Moreau (1975) state that for a given confidence level and margin of error, the necessary sample size, and hence sampling frequency, is proportional to the variance. Since the variance of water quality parameters may differ considerably over time, the frequency requirements of a monitoring program may vary depending on the time of the year. Sampling frequency will need to be greater during periods of greater variance.

There are statistical methods for estimating the number of samples required to achieve a desired level of precision in random sampling (Cochran, 1963), stratified random sampling (Reckhow, 1979), cluster sampling (Cochran, 1977), multistage sampling (Gilbert, 1987), double sampling (Gilbert, 1987), and systematic sampling (Gilbert, 1987). For a more detailed discussion of sampling theory and statistics, see *Samples and Sampling*.

## **b. Sampling Interval**

A method for estimating sampling interval is provided by Sherwani and Moreau (1975). They note that the least favorable sampling interval for parameters that exhibit a periodic structure is equal to the period or an integral multiple of the period. Such sampling would introduce statistical bias. Reckhow (1979) points out that, for both random and stratified random sampling, systematic sampling is acceptable only if "there is no bias introduced by incomplete design, and if there is no periodic variation in the characteristic measured." Gaugush (1986) states that monthly sampling is usually adequate to detect the annual pattern of changes with time.

## **c. Some Recommendations**

It is generally recommended that the sampling of plankton, fish, and benthic organisms in estuaries should be seasonal, with the same season sampled in multiyear studies (USEPA, 1991a). The aerial coverage and bed density for submerged aquatic vegetation (SAV) vary from year to year due to catastrophic storms, exceptionally high precipitation and turbidity, and other poorly understood natural phenomena (USEPA, 1991a). For this reason, short-term SAV monitoring may be more reflective of infrequent impacts and may not be useful for trend assessment. In addition, incremental losses in wetland acreage are now within the margin of error for current detection limits. It is recommended that SAV and wetland sampling be conducted during the period of peak biomass (USEPA, 1991a).

The frequency of sediment sampling in estuaries should be related to the expected rate of change in sediment contaminant concentrations (USEPA, 1991a). Because tidal and seasonal variability in the distribution and magnitude of several water column physical characteristics in estuaries is typically observed, these influences should be accounted for in the development of sampling strategies (USEPA, 1991a).

For monitoring the state of biological variables, the length of the life cycle may determine the sampling interval (Coffey and Smolen, 1990). EPA (1991b) recommends a minimum of 20 evenly spaced (e.g., weekly) samples per year to document trends in chemical constituents in watershed studies lasting 5 to 10 years. The 20 samples should be taken during the time period (e.g., season) when the benefits of implemented pollution control measures are most likely to be observed. For benthic macroinvertebrates and fish, EPA recommends at least one sample per year.

## **8. Sampling Techniques**

### **a. Automated Sampling to Estimate Pollutant Loads**

Typical methods for estimating pollutant loads include continuous flow measurements and some form of automated sampling that is either timed or triggered by some feature of the runoff hydrograph. For example, in the Santa Clara watershed of San Francisco Bay, flow was continuously monitored at hourly intervals, wet-weather monitoring included collection of flow-composite samples taken with automatic samplers, and dry-weather monitoring was conducted by obtaining quarterly grab samples (Mumley, 1991). Data were used to estimate annual, wet-weather, and dry-weather copper loads.

In St. Albans Bay, Vermont, continuous flow and composite samples were used to estimate nutrient loads for trend analysis (Vermont RCWP, 1984). In the Nationwide Urban Runoff Program (NURP) project in Bellevue, Washington, catchment area monitoring included continuous gauging and automatic sampling that occurred at a preset time interval (5 to 50 minutes) once the stage exceeded a preset threshold (USEPA, 1982b).

### **b. Grab Sampling for Pollutant Loads**

Grab sampling with continuous discharge gauging can be used to estimate load in some cases. Grab sampling is usually much less expensive than automated sampling methods and is typically much simpler to manage. These significant factors of cost and ease make grab sampling an attractive alternative to automated sampling and therefore worthy of consideration even for monitoring programs with the objective of estimating pollutant loads.

Grab sampling should be carefully evaluated to determine its applicability for each monitoring situation (Coffey and Smolen, 1990). Nonpoint source pollutant concentrations generally increase with discharge. For a system with potentially lower variability in discharge, such as irrigation, grab sampling may be a suitable sampling method for estimating loads (Coffey and Smolen, 1990). Grab sampling may also be appropriate for systems in which the distribution of annual loading occurs over an extended period of several months, rather than a few events. In addition, grab sampling may be used to monitor low flows and background concentrations.

For systems exhibiting high variability in discharge or where the majority of the pollutant load is transported by a few events (such as snowmelt in some northern temperate regions), however, grab sampling is not recommended.

### **c. Habitat Sampling**

EPA recommends a procedure for assessing habitat quality where all of the habitat parameters are related to overall aquatic life use support and are a potential source of limitation to the aquatic biota (Plafkin et al., 1989). In this procedure, EPA begins with a survey of physical characteristics and water quality at the site. Such physical factors as land use, erosion, potential nonpoint sources, stream width, stream depth, stream velocity, channelization, and canopy cover are addressed. In addition, water quality parameters such as temperature, dissolved oxygen, pH, conductivity, stream type, odors, and turbidity are observed.

Then, EPA follows with the habitat assessment, which includes a range of parameters that are weighted to emphasize the most biologically significant parameters (Plafkin et al., 1989). The procedure includes three levels of habitat parameters. The primary parameters are those that characterize the stream "microscale" habitat and have the greatest direct influence on the structure of the indigenous communities. These parameters include characterization of the bottom substrate and available cover, estimation of embeddedness, and estimation of the flow or velocity and depth regime. Secondary parameters measure the "macroscale" and include such parameters as channel alteration, bottom scouring and deposition, and stream sinuosity. Tertiary parameters include bank stability, bank vegetation, and streamside cover.

MacDonald (1991) discusses a wide range of channel characteristics and riparian parameters that can be monitored to evaluate the effects of forestry activities on streams in the Pacific Northwest and Alaska. MacDonald states that "stream channel characteristics may be advantageous for monitoring because their temporal variability is relatively low, and direct links can be made between observed changes and some key designated uses such as coldwater fisheries." He notes, however, that "general recommendations are difficult because relatively few studies have used channel characteristics as the primary parameters for monitoring management impacts on streams."

On the other hand, MacDonald concludes that the documented effects of management activities on the stability and vegetation of riparian zones, and the established linkages between the riparian zone and various designated uses, provide the rationale for including the width of riparian canopy opening and riparian vegetation as recommended monitoring parameters. Riparian canopy opening is measured and tracked through a historical sequence of aerial photographs (MacDonald, 1991). Riparian vegetation is measured using a range of methods, including qualitative measures of vegetation type, visual estimations of vegetation cover, quantitative estimations of vegetation cover using point- or line-intercept methods, light intensity measurements to estimate forest cover density, stream shading estimates using a spherical densiometer, and estimates of vegetation density based on plot measurements.

Habitat variables to monitor grazing impacts include areas covered with vegetation and bare soil, stream width, stream channel and streambank stability, and width and area of the riparian zone (Platts et al., 1987). Ray and Megahan (1978) developed a procedure for measuring streambank morphology, erosion, and deposition. Detailed streambank inventories may be recorded and mapped to monitor present conditions or changes in morphology through time.

To assess the effect of land use changes on streambank stability, Platts et al. (1987) provide methods for evaluating and rating streambank soil alteration. Their rating system can be used to determine the conditions of streambank stability that could affect fish. Other measurements that could be important for fisheries habitat evaluations include streambank undercut, stream shore water depth, and stream channel bank angle.

#### **d. Benthic Organism Sampling**

Benthic communities in estuaries are sampled through field surveys, which are typically time-consuming and expensive (USEPA, 1991a). Sampling devices include trawls, dredges, grabs, and box corers. For more specific benthic sampling guidance, see Klemm et al. (1990).

#### **e. Fish Sampling**

For estuaries and coastal waters, a survey vessel manned by an experienced crew and specially equipped with gear to collect organisms is required (USEPA, 1991a). Several types of devices and methods can be used to collect fish samples, including traps and cages, passive nets, trawls (active nets), and photographic surveys. Since many of these devices selectively sample specific types of fish, it is not recommended that comparisons be made among data collected using different devices (USEPA, 1991a).

#### **f. Shellfish Sampling**

Pathobiological methods provide information concerning damage to organ systems of fish and shellfish through an evaluation of their altered structure, activity, and function (USEPA, 1991a). A field survey is required to collect target organisms, and numerous tissue samples may be required for pathobiological methods. In general, pathobiological methods are labor-intensive and expensive (USEPA, 1991a).

#### **g. Plankton Sampling**

Phytoplankton sampling in coastal waters is frequently accomplished with water bottles placed at a variety of depths throughout the water column, some above and some below the pycnocline (USEPA, 1991a). A minimum of four depths should be sampled. Zooplankton sampling methods vary depending on the size of the organisms. Devices used include water bottles, small mesh nets, and pumps (USEPA, 1991a).

#### **h. Aquatic Vegetation Sampling**

Attributes of emergent wetland vegetation can be monitored at regular intervals along a transect (USEPA, 1991a). Measurements include plant and mulch biomass, and foliar and basal cover. Losses of aquatic vegetation can be tracked through aerial photography and mapping.

### **i. Water Column Sampling**

In estuaries and coastal waters, chemical samples are frequently collected using water bottles and should be taken at a minimum of four depths in the vertical profile (USEPA, 1991a). Caged organisms have also been used to monitor the bioaccumulation of toxic chemicals.

Physical sampling of the water column at selected depths in estuaries is done with bottles for temperature, salinity, and turbidity, or with probes for temperature and salinity (USEPA, 1991a). Current meters are used to characterize circulation patterns.

### **j. Sediment Sampling**

Several types of devices can be used to collect sediment samples, including dredges, grabs, and box corers (USEPA, 1991a). Sampling depth may vary depending on the monitoring objective, but it is recommended that penetration be well below the desired sampling depth to prevent sample disturbance as the device closes (USEPA, 1991a). EPA also recommends the selection of sediment samplers that also sample benthic organisms to cut sampling costs and to permit better statistical analyses relating sediment quality to benthic organism parameters.

### **k. Bacterial and Viral Pathogen Sampling**

For estuaries and coastal waters it is recommended that samples be taken of both the underlying waters and the thin microlayer on the surface of the water (USEPA, 1991a). This is recommended, despite the fact that standardized methods for sampling the microlayer have not been established, because research has shown bacterial levels several orders of magnitude greater in the microlayer. In no case should a composite sample be collected for bacteriological examination (USEPA, 1978).

Water samples for bacterial analyses are frequently collected using sterilized plastic bags or screw cap, wide-mouthed bottles (USEPA, 1991a). Several depths may be sampled during one cast, or replicate samples may be collected at a particular depth by using a Kemmerer or Niskin sampler (USEPA, 1978). Any device that collects water samples in unsterilized tubes should not be used for collecting bacteriological samples without first obtaining data that support its use (USEPA, 1991a). Pumps may be used to sample large volumes of the water column (USEPA, 1978).

## **9. Quality Assurance and Quality Control**

Effective quality assurance and quality control (QA/QC) procedures and a clear delineation of QA/QC responsibilities are essential to ensure the utility of environmental monitoring data (Plafkin et al., 1989). Quality control refers to the routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurement process. Quality assurance includes the quality control functions and involves a totally integrated program for ensuring the reliability of monitoring and measurement data.

EPA's QA/QC program requires that all EPA National Program Offices, EPA Regional Offices, and EPA laboratories participate in a centrally planned, directed, and coordinated Agency-wide QA/QC program (Brossman, 1988). This requirement also applies to efforts carried out by the States and interstate agencies that are supported by EPA through grants, contracts, or other formalized agreements. The EPA QA program is based on EPA order 5360.1, which describes the policy, objectives, and responsibilities of all EPA Program and Regional Offices (USEPA, 1984).

Each office or laboratory that generates data under EPA's QA/QC program must implement, at a minimum, the prescribed procedures to ensure that precision, accuracy, completeness, comparability, and representativeness of data are known and documented. In addition, EPA QA/QC procedures apply throughout the study design, sample collection, sample custody, laboratory analysis, data review (including data editing and storage), and data analysis and reporting phases.

Specific guidance for QA/QC is provided for EPA's rapid bioassessment protocols (Plafkin et al., 1989) and for EPA's Ocean Data Evaluation System (USEPA, 1991a). Standardized procedures for field sampling and laboratory methods are an essential element of any monitoring program.

#### **D. Data Needs**

Data needs are a direct function of monitoring goals and objectives. Thus, data needs cannot be established until specific goals and objectives are defined. Furthermore, data analyses should be planned before data types and data collection protocols are agreed upon. In short, the scientific method, defined as "a method of research in which a problem is identified, relevant data gathered, an hypothesis formulated, and the hypothesis empirically tested" (Stein, 1980), should be applied to determine data needs. Types of data generally needed for nonpoint source monitoring programs will include chemical, physical, and biological water quality data; precipitation data; topographic and morphologic data; soils data; land use data; and land treatment data. The specific parameters should be determined based on site-specific needs and the monitoring objectives that are established.

Under EPA's quality assurance and quality control (QA/QC) program (see Quality Assurance and Quality Control), a full assessment of the data quality needed to meet the intended use must be made prior to specification of QA/QC controls (Brossman, 1988). The determination of data quality is accomplished through the development of data quality objectives (DQOs), which are qualitative and quantitative statements developed by data users to specify the quality of data needed to support specific decisions or regulatory actions. Establishment of DQOs involves interaction of decision makers and the technical staff. EPA has defined a process for developing DQOs (USEPA, 1986).

# **Appendix 12**

## **Example Site Location Form** **(courtesy of Alliance for the Chesapeake Bay)**



Office Use Only  
**Monitoring Coordinator:** \_\_\_\_\_  
**Site Designation:** \_\_\_\_\_  
**Tributary:** \_\_\_\_\_  
**Date Site Information entered into database:** \_\_\_\_\_

## ACB Citizen Monitoring Site Documentation

**Instructions:** Please fill in this form as fully and accurately as possible. The information you provide will be used to document monitoring site locations. Be as descriptive as you can. We need to have precise site documentation to enable the location of your site in the future. In each of the Sections, circle the option that applies.

SITE NAME: \_\_\_\_\_  
 PRIMARY MONITOR'S NAME: \_\_\_\_\_  
 BACK-UP MONITOR'S NAME: \_\_\_\_\_  
 DATA COLLECTION START DATE: \_\_\_\_\_

### I. Location Description: (Please Circle)

Tidal                      Nontidal                      Lake  
 Water body (What Creek, Stream, River, Lake the site is on)

Other Location

Details: \_\_\_\_\_

### II. Collection Description: (Please Circle)

Shoreline                      Pier/Dock                      Bridge crossing  
 Boat                      Wading to Stream Center

### III. Coordinates:

\*A USGS 7-minute quadrangle map or a GPS Unit are the recommended methods for determining site coordinates. You can find all USGS quadrangle maps online for free by going to <http://www.topozone.com>. You may search by place name or by river name by choosing the link titled "Place Name Search" under "Get A Map". Once you have located your site, you may zoom in by clicking on the 1:25,000 button in the top left corner above the map. Use your mouse to click on the exact location- a red crosshair will appear over your site. Choose "DD.DDDD" (decimal degrees) as the coordinate type located beneath the map. The coordinates will then be listed in these units above the map. You can then either print the map, or email it to us. You can also find USGS maps for local areas at libraries, fishing and camping stores, and engineering and architectural supply stores. Cost is about \$3.00 a map.

**Please Put in Units in Decimal Degrees (DD.DDDD)**

**LATITUDE:** \_\_\_\_\_ **LONGITUDE:** \_\_\_\_\_

(Example: 37.1234)

(Example: -77.1234)

☐ MAP- Please attach a map of your site to this form, with the site labeled.\*

☐ PHOTO DOCUMENTATION- It is recommended that you visually document your site with photographs of the monitoring location looking upstream and downstream. Label the photos accordingly, and attach copies to this form.

(Updated 11/18/02)

## **Appendix 13**

### **Handout from Virginia Water Monitoring Council's Quality Assurance/Quality Control Forum**

## Basic QA/QC Concepts

Modified from *The Volunteer Monitor's Guide to Quality Assurance Project Plans*. EPA 841-B-96-003. September 1996. This guide is recommended for all citizen monitoring organizations in Virginia interested in developing a quality assurance project plan. The guide is available online at [www.epa.gov/owow/monitoring/volunteer/](http://www.epa.gov/owow/monitoring/volunteer/).

### Quality Assurance (QA)

Refers to a broad plan for maintaining quality in all aspects of a program, including all quality control measures, sample collection, sample analysis, data management, documentation, evaluation, *etc.* It is helpful to data users in determining the integrity (soundness) of data.

### Quality Control (QC)

The steps, including measurements, calibrations, and standardization practices, taken to assure the quality of specific sampling and analytical procedures. QC is used to reduce error in the data collection and analysis. For example, the collection of two samples (QC samples) taken at the same time and location should yield the same (or very similar) results; data quality can be determined by evaluating the results of the QC samples and determining precision and accuracy. The decision to accept data, reject it, or accept only a portion of it should be made after analysis of the QC data.

### Quality Assurance Project Plan (QAPP)

The formal written document describing the detailed quality assurance procedures and QC activities that will be used to assure data quality.

### Precision

Degree of agreement among repeated measurements. Reproducible results are precise. Can be calculated using the standard deviation (a statistical way to measure variation around the data set's average value).

### Accuracy

Measures how close your results are to a *true* value. The smaller the difference between the measurement and its "true" value, the more accurate the measurement. Found by analyzing a standard or reference sample (one with a known value).

### Representativeness

The extent to which measurements actually depict the true condition being evaluated. For example, data collected just below a pipe outfall are not representative of the entire stream.

### Completeness

The number of samples and documentation needed to meet the sampling objectives. Volunteers may not be able to collect as many samples as planned so try to take more samples than you expect to need.

### **Comparability**

The extent to which data from one study can be directly compared to either past data obtained in the study or from data obtained in another study.

### **Detection Limit**

In general, the lowest concentration of a given parameter your method or equipment can reliably detect and report as greater than zero. For example, if an instrument has a detection limit of 1 ppb (parts per billion) and a sample contains 0.5 ppb of lead, the sample will be “below the detection limit.” Note, this does not mean the sample is free of lead (0 ppb), simply that the amount of lead is less than the instrument can detect.

### **Metadata**

Metadata is data about the data. It describes the data information presented in a given dataset and quality criteria associated with their generation. Metadata is all other data collected that is not the actual value of the parameter measured. Metadata provides information on the procedures used, quality control measures, site locations, sample collectors, quality of the data, etc.

### **Standard Operating Procedures (SOPs)**

Written instructions, which describe the step-by-step procedures for a process. For example, the procedures for collecting a water sample are referred to as field SOPs while the procedures for analyzing the sample in a lab are referred to as the lab SOPs.

Information provided by the **Virginia Water Monitoring Council (VWMC)**. To join the VWMC, contact **Jane Walker** at **540-231-4159** or [vwmc@vt.edu](mailto:vwmc@vt.edu). A special thank you to DEQ for assistance with this handout.



## **Appendix 14**

# **Quality Assurance Project Plan Template and Directions**

## The Twenty Four Steps to Develop a Quality Assurance Project Plan

Developed by James Beckley

June 5, 2007

**Purpose:** Following the directions below will allow users to develop a Virginia Department of Environmental Quality (DEQ) approved Quality Assurance Project Plan (QAPP). A template to fill out the QAPP is available at <http://www.deq.virginia.gov/cmonitor/grant.html> or by contacting James Beckley at [jebeckley@deq.virginia.gov](mailto:jebeckley@deq.virginia.gov). A QAPP is important to show that the group followed acceptable sample collection and test procedures. A QAPP also serves as a troubleshooting guide to identify and correct quality assurance problems.

**Background:** Prior to beginning to develop a QAPP, it is best to know the goals that the group wants to achieve through monitoring. Completing a monitoring plan prior to starting a QAPP is extremely helpful in planning the monitoring project. The Citizen Monitoring Plan template found at [www.deq.virginia.gov/cmonitor/grant.html](http://www.deq.virginia.gov/cmonitor/grant.html) is an excellent resource.

**Procedure:** Developing a QAPP can require several revisions due to missing or incorrect information. To prevent the need for unnecessary revisions, please follow the directions below. Contact James Beckley at (804) 698-4025 or at [jebeckley@deq.virginia.gov](mailto:jebeckley@deq.virginia.gov) if you have any questions.

### Step 1- Title and Approval Page:

This is the first page of the QAPP. Congratulations on beginning the process to develop a scientifically based QAPP. Much like a book cover, the title and approval pages identify the project, the name of the monitoring group, and the date of the QAPP submission.

Under the heading is a section to place the name of the various people involved with conducting and reviewing the QAPP. Usually, there are four people involved with developing a QAPP. These people are the project manager for the group, the Quality Assurance (QA) officer of the group, DEQ data liaison (James Beckley), and DEQ QA officer.

### Step 2- Table of Contents:

Please provide the page numbers for each section covered in the QAPP template. Please include a list of appendices for tables, figures, pictures, reference page(s), and similar items.

### Step 3- Distribution List:

In this part, the group will list the people who will receive a copy of the QAPP. Unlike *Step 1- Title and Approval Page*, this section covers people not directly involved in the development of the QAPP but is involved in the monitoring project.

### Step 4- Project/ Task Organization:

In this step, please identify the key personnel in your project and their duties. These can include such positions as:

- The project manager (usually the leader of the group)
- A QA officer (ensures that samples and tests are being done correctly)
- Field leader (oversees sample collection teams)
- Field monitors (volunteers who collect and/or test samples in the field)
- Laboratory manager (oversees the lab where samples are being analyzed)
- Laboratory technicians (laboratory staff who may be actually testing the samples)

Next to each position should be a brief description of that position's responsibility in the project. In addition, please mention who the intended audience is who will look at the monitoring data.

To help organize this information, it may be wide to develop an organizational chart. This chart can clearly show the structure of the group and identify which person is the best to answer a specific question. Computer programs like Microsoft® Word offer tools to help make these charts.

**Step 5- Problem Definition/ Project Background:**

This step is composed of two sections. The purpose is to describe why the group is doing monitoring at the selected sites and includes background information for people not familiar with the project.

***Section A. Problem Statement:***

In this section, describe the reason why the group is doing this project. If you have already completed a monitoring plan worksheet, you can take this directly from Step 1 of the worksheet. If not, simply state the reasons why you wish to do this project.

**Example:**

Previous monitoring in Bob's Creek in Smith County has shown high levels of E. coli bacteria. By setting up additional sampling stations along the creek, we will be able to identify the source of the E. coli bacteria. We believe the source is due to failing septic tanks and runoff from a nearby cattle farm.

***Section B. Intended Usage of Data:***

In this part, the group will describe how they intend to use the data. Again, you can pull this directly from the monitoring plan worksheet under Step 3. If not, list how you will use the data and who the intended users of the data are.

**Example:**

We intend to use the data to identify possible pollution sources in Bobs Creek. We will share our findings with the local government, soil and water conservation district, DEQ, and local citizens.

**Step 6- Project/ Task Description:**

As the title implies, this step of the QAPP process deals with developing an outline concerning when performing each task and what the tasks are.

***Section A. General Overview of Project:***

This section helps give a brief overview of the project. It is important to include such items as the water quality parameters the group is testing for and the methods to collect samples. In addition, it is good to identify which tests are the most critical and which are of secondary importance. You can obtain most of this information from Steps 5 and 6 of a completed Monitoring Plan.

***Section B. Project Timetable:***

This section deals with the timetable for the project. A well-planned timeline can help prevent bottlenecks from conflicting project tasks. The group should consider expected weather conditions and other events that could delay completing certain project tasks. For the timeline, include important tasks such as planned sampling dates (i.e. 2ed Tuesday of every month), data entry and report deadlines.

There are many different formats for developing a project timeline. The QAPP template uses a table-based timeline. In the first column, you would list the project task. The second column is where you would place the start date for the task. The third column would then list the expected completion date for that task. Please note that by overlapping two activities start and/or ending dates, you may experience scheduling problems.

Another popular method used by volunteer groups is to make a project timeline. The timeline format can graphically show the lifespan of each project task. This may make it easier to see overlapping tasks and project bottlenecks. Using this method, place each project tasks along the timeline according to the start and end dates for each task. Be sure to identify these dates on the timeline.

#### **Step 7- Measurement Quality Objectives: (AKA Data Quality Objectives)**

Now we are starting to move past the introductory and planning phases of the QAPP. The following steps are where most volunteer groups have trouble in getting the QAPP approved by DEQ. It is important to receive input from laboratory and sample teams when writing the remainder of the QAPP. You will refer back to this section when you are completing *Step 24- Reconciliation with Data Quality Objectives*

#### **Section A. Data precision, Accuracy, and Measurement Range:**

For the first section, the group must list each water quality parameter that the group plans to test for. For most water quality parameters (pH, DO, E. coli, etc), it is best to use a table format

##### **Example:**

<b>Matrix</b>	<b>Parameter</b>	<b>Measurement Range</b>	<b>Accuracy</b>
Water	TKN	0.5 mg/L- 25 mg/L	+/- 0.5 mg/L
Water	pH	6.0 – 8.0 S.U.	0.2 S.U.
Sediment	Lead	5.0 ug/L-10,000 ug/L	0.02 ug/L

In filling out section 7A, it is important to know some basic definitions. Below are definitions for matrix, parameter, measurement range, and accuracy.

**Matrix-** Is defined as where you are taking samples from. Most groups will list ‘water’ as the matrix for sampling most chemical parameters. A group would use list ‘sediment’ as the matrix when sampling for benthic macroinvertebrates because the animals live in the rocks and sediment of a streambed.

**Parameter-** Is defined as the actual substance that you are testing for (i.e. pH, DO, E. coli, etc.)

**Measurement Range-** shows the range that a test method can detect. The manufacturer of the test equipment, test procedure, or the laboratory that will test samples can supply this information.

**Accuracy-** shows how close a sample result is to the actual value. Think of it as aiming for the bull’s eye of a dartboard. Like in darts, it is impossible to have perfect accuracy in testing water samples.

Most laboratories and probe manufacturers can provide the measurement range and level of accuracy for the equipment and methods used. In some cases, the measurement range and/or level of accuracy may not be sufficient to produce reliable or meaningful data. The DEQ QA officer can give advice on acceptable levels of accuracy.

#### **Section B. Data Representativeness:**

When collecting water samples, it is important to collect a sample that represents the actual stream conditions. In this section, the group must state how they selected their sample sites. The group should

note such items as number of sample sites, location of the sites, time needed to sample each site, safety factors, and similar items.

It is highly recommended when planning your sampling schedule, to have the group sample at multiple sites at the same time. This will give a snapshot for the entire study area to show water quality at each sample site. This is a great sampling methodology but it may require multiple sample teams.

**Section C. Data Comparability:**

In this section, the group should state the methods for testing water samples. You can provide a summary of the test methods in this section. If you decide to do so, please include a full description of the methods as an attachment.

For DEQ to approve a QAPP the group should use EPA and/or DEQ approved methods. The website <http://www.nemi.gov> offers free downloads of EPA approved methods. You can also contact local laboratories, college science departments, or your local EPA and DEQ offices.

**Section D. Data Completeness:**

The volunteer group must determine how much data they need to get accurate results. A good QAPP should include extra samples to act as a buffer in the event such as bad weather or if a sample is lost.

For the sample completeness percentage, the group should have a goal in mind. This will help determine the minimum number of samples you need to meet this goal. Depending on the sample size, most groups have a goal of 80 to 95% completeness. The volunteer group QA officer and the DEQ QA officer can help set this goal.

**Step 8- Training Requirements and Certification:**

For most groups, volunteers may not have a lot of knowledge of EPA or DEQ approved methods. Therefore, it is important for volunteers to receive training and certification. Even groups that have seasoned volunteers occasionally need retaining to reinforce sampling and test methods.

You can use the information from Step 10, Part A of a completed Monitoring Plan. Normally, most groups do training or recertification once each year. Include a brief summary of what the training session will include.

Example:

Every year, volunteers meet to receive training and recertification. Volunteers bring in their sampling equipment to check for wear and maintenance. The QA officer calibrates sample team thermometers with an NIST certified thermometer. Sample team volunteers are tested, and if necessary, retrained to collect temperature, pH, and DO samples following the DEQ approved SOP. Sample teams properly dispose of expired reagents and receive fresh reagents.

If you are unsure about the frequency and type of recertification you will need, please contact James Beckley at [jebeckley@deq.virginia.gov](mailto:jebeckley@deq.virginia.gov) or by phone at (804) 698-4025.

**Section A. Training Logistical Arrangements:**

The purpose of this section of the QAPP is to outline the training necessary for various group members. Most training and certification should occur at least an annual basis. Some tests may require more frequent retraining or supervision.

For this section of the QAPP, the training schedule can be in a table format. In some cases, the volunteer group may wish to write out a description of the training. The group should include items such as what the training involves and how frequent the training should occur.

***Section B. Description of Training and Trainer Qualifications:***

This section is where the group will write out what the training program will involve. Please include who will do the training, what the training will cover, and how to demonstrate that volunteers learned from the training.

**Example:**

The group leader and QA officer will lead the training and recertification. Group volunteers will observe how to do the tests for pH, DO, and temperature and record the information correctly on the calibration sheet. Volunteers will then perform each test while being observed by the group leader or QA officer. If the volunteer makes a mistake, the observer will bring it to their attention and explain the problem. Once the volunteer is able to do the test correctly, the observer will sign off that they have passed training.

**Step 9- Documentation and Records:**

This step deals with how the volunteer group will record and store their data. Please also note the amount of time that the group will hold onto the data (usually 3 or more years) and who is responsible for keeping the data. In addition, please include a blank copy of the data forms mentioned below as an attachment.

- Raw data sheets
- Field sampling sheets or field logs
- Laboratory datasheets
- Calibration logs for probes and other calibrated equipment
- Chain of custody forms (normally used when sending samples to a lab)
- Any other quality control or data reporting sheets

**Step 10- Sampling Process Design:**

This deals with the actual monitoring project and pulls some information from earlier sections of the QAPP and the Monitoring Plan.

***Section A. Rationale for Selection for Sampling Sites:***

Here the volunteer group will identify sample site locations, and state why these are good sample sites. It is important to list any safety considerations for the sample sites. The group does not need to go into detail about how the samples are collected but they should reference a developed Standard Operational Procedure (SOP). A copy of the SOP should be included when submitting the QAPP.

It is helpful but not necessary to include a map showing the locations of the sample sites. If a map is not available, please be sure to include the latitude and longitude of the sample sites in a table. You can access a free mapping service at <http://www.topozone.com> to find latitude and longitude of sample sites. Please record the latitude and longitude from each site in a table and include this table as an attachment.

***Section B. Sample Design Logistics:***

This section is where the volunteer group will describe the details of their monitoring project. Some items covered under this section are the following.

- Monitoring Parameters (Example: DO; pH; etc)
- Monitoring frequency (Example: 1 sample per month, quarterly, etc.)

- Monitoring Period (Example: ongoing, December of 2007, etc.)

The best way to show this information is in a table format provided in the QAPP template. The table has separate sections to show physical, chemical, and biological parameters.

### Step 11- Sampling Method Requirements:

Here the volunteer group will list specific details of the type of monitoring equipment or test procedures. If you are working with a laboratory, they can help you prepare this section.

The table provided in the QAPP template has three sections.

- Monitoring Parameters (E. coli, nutrients, etc.)
- Monitoring equipment used (Sample bucket, sample bottle, etc)
- Sample method used (sample bucket, direct collection from the stream, etc.

If you are using a method unfamiliar with DEQ, you will need to provide a description of the method in the QAPP. You can either list this under Step 11 or as an attachment. You should include the following:

- How a volunteer collects the samples
- What (if any) storage equipment is used to collect the samples
- Any decontamination of sampling equipment necessary prior to collecting the next sample

### Step 12- Sample Handling and Custody Procedures:

**Note:** If the group performs all tests at the sample site, this section may not be necessary.

Volunteers that collect samples in the field to ship to a laboratory or given to another volunteer for analysis will need to develop a chain of custody procedure. This helps track down any shipping or storage problems with a sample. In addition, when using a laboratory, the lab needs to identify your samples from other samples they may receive at the same time. Many laboratories have their own chain of custody forms and can help you when preparing this part of the QAPP.

To develop your own chain of custody, you will need to write the shipping procedures for samples going to a laboratory. It is important to cover every step of the process from sample collection to arriving at the laboratory. These steps include sample collection, transport, storing, analyzing, and disposing of samples. There should be clear labels for each sample bottle and should, at a minimum, include the following:

Sample date/time:	Sample Location:	Sample number:
Preservative used (if any):	Sample collector:	Sample type:

In addition, a chain of custody should be on file. The volunteer can make the chain of custody form if the laboratory performing the analysis does not have one available. The chain of custody form should include at a minimum:

- The date/time of sample collection
- Who collected the sample?
- Date/Time sample was relinquished along with signature of both the sample collector and the shipping party
- A date/time of sample arrival to the laboratory along with the signature of the shipping party and the laboratory worker who received the sample.

Please include a blank copy of this form in the final copy of the QAPP.

### **Step 13-Analytical Methods Requirements:**

In this step, please write out the test methods and specific equipment used to conduct the study. You can go to <http://www.nemi.gov> to find approved methods for water sampling. Please list these methods (i.e. EPA method 351.4).

If you are using a non-standard method, please describe the method or site and attach the procedure from the SOP of the volunteer group.

### **Step 14- Quality Control Requirements:**

This is a critical section of any sound QAPP. Here, the volunteer group should describe they will ensure data reliability from using field equipment and laboratory procedures. The term Quality Control (QC) describes these steps. You can complete the following sections using a table or with a written description.

#### ***Section A. Field QC checks:***

Under this section, the group must describe the methods used to test and/or collect field samples. Such descriptions include but are not limited to: taking multiple samples at the same location, field blanks, and split samples. Please refer to [http:// www.epa.gov/owow/monitoring/volunteer/qapp/qappch3.pdf](http://www.epa.gov/owow/monitoring/volunteer/qapp/qappch3.pdf) for other field QC methods. If the group is using a non-standardized method, please write out the procedure.

#### ***Section B. Laboratory QC Checks:***

**Note:** This section is not necessary for volunteer groups who are running tests only in the field.

Laboratories that test the group's field samples should be able to provide this information. You can attach this to the QAPP. If the group does not use a laboratory but runs tests away from the field, the group will have to complete this section. The group must write out the entire QC protocols in either a narrative or table form in this section. Again, refer to the web address listed in the section above for more information.

#### ***Section C. Data Analysis QC Checks:***

If there is a problem in sample analysis or incorrect sampling procedures, it is important show how the group will correct the problem. In this section, please write out what steps the group will take to correct any problems.

Such examples include retraining of samplers, and rerunning tests with new reagents. Many other methods are available based on the problem you encounter. For the purposes of a draft QAPP to DEQ, general details for this section are acceptable.

### **Step 15- Instrument/Equipment Testing, Inspection, and Maintenance Requirements:**

It is important to identify and fix equipment when it fails. To prevent equipment failure, there needs to be a regular maintenance and inspection schedule. The schedule should cover field and laboratory equipment, and sample sites.

In a narrative or table based format, the monitoring group must describe the following steps.

- Type of sampling or test equipment/instruments used
- Frequency of inspection for defects or damage
- Who will do the inspection and the inspection procedure
- How the equipment will be maintained during and after sample runs

For instruments such as pH probes, most manufacturers provide this information in the instrument manual. Please include a copy of this information when submitting the QAPP and in your SOP.

**Step 16- Instrument calibration and Frequency:**

Over time, the equipment used to take and test water samples will lose their accuracy. Regular calibrations will prevent this from occurring. For equipment such as pH probes, the user's manual should have this information. If a laboratory is testing samples, they should be able to provide their calibration information.

In a narrative or table format, describe the following:

- What equipment needs calibration
- How often the equipment needs calibration
- What standards or other instruments used to perform the calibration
- How and where calibration records will be stored for future review and reference

**Step 17- Inspection/Acceptance Requirements for Supplies:**

Data is only as good as the supplies used in collecting and running of the samples. These include sample bottles, reagents, and other items. Please write a brief description on how to inspect the sampling equipment. In addition, state what the group will do if they receive damaged equipment or other unacceptable equipment. For example, if there is expired pH buffer, the group can use the buffer for training purposes.

**Step 18- Data Acquisition Requirements:**

It is important to list any outside data sources used in developing the monitoring project. This will give credit for other groups work and help separate your data from another source. Such examples include:

- Use of USGS topographic maps
- Data from other monitoring groups
- Historical information
- Any other similar sources of data.

**Step 19- Data Management:**

This part of the QAPP deals with how the group will manage the collected data. In this step, please describe the resources that group used to record the data. Such items include the following:

- Type of data storage media (Example: CD R/RW)
- Computer operating system (Example: Windows® 2000)
- Data management programs (Example: Microsoft® Excel)
- Plan to check raw data sheets to the final database to ensure accurate and complete data entry

**Step 20- Assessments and Response Actions:**

In this step, describe how the group will evaluate field and laboratory sampling, data management, and group members. Here you would include some of the following procedures:

- Visits of sample teams in the field and laboratory members
- Sampling and testing review sessions with field and laboratory members
- Audits of test procedures and methods

The sample team leader and/or QA officer should lead all reviews under this step. In addition, there should be a mention on what the group will do if there are problems found with a sample team or testing procedure such as retraining. This should include who will administer the corrective actions.

**Step 21- Reports:**

Describe the types of reports, frequency of reporting, and to who will receive the reports. These reports include such things as quarterly progress reports, monthly sample results, internal assessments, audits, and the final report. Other reports are also possible based on the scope of the project.

**Step 22- Data Review, Validation, and Verification:**

Based on collecting and assessing the data, it is time to see if the data would be valid or rejected based on meeting the objectives set out by the QAPP. Please describe who is responsible in reviewing the data. Please include brief summary on how the person will do the review.

**Example:**

The QA officer and sample team leader review the data collected by the sample volunteers. Any questions with the data will be asked to the stream sampler and/or laboratory manager. If data is in need of correction, the QA officer and sample team leader will flag and document the data for future review. Decisions to reject data not meeting quality assurance will be done through agreement of the QA officer and sample team leader.

**Step 23- Validation and Verification Methods:**

The previous step of the QAPP dealt with who will be responsible for reviewing the data. This step covers the methods that the person will review and validate the data. Such examples include:

- Use of sample spikes and other QC steps as mentioned in *Part 14- Quality Control Requirement*
- Confirming computer-entered data with actual field sheets
- Ensuring proper filling out of chain of custody forms
- Equipment calibration frequency

Also, include a section discussing if the person finds errors in the data, how they plan to correct the errors.

**Step 24- Reconciliation with Data Quality Objectives (DQO):**

After completing the previous 23 steps, we are now at the last step in the QAPP. We are now at the final step of the QAPP development process!

In this final step, the group should describe if the data generated by the project met with the objectives of the project. The best way to do this is to compare and analyze the project data for completeness, accuracy, precision, representativeness, and comparability. Compare these items to those outlined in the preceding parts of the QAPP. If the data does not meet with the planned goals, describe how the group will correct the problem and why it occurred. Discarding of some data, revising the project DQO, or setting limits on how unusable data is acceptable in these situations. Please also state who will receive any data corrections.

Congratulations for completing the QAPP process! Remember that you can modify the QAPP at any time to adapt to new situations. If you wish to change your QAPP, please notify everyone in Step 1 and 3 to these changes.

# Quality Assurance Project Plan

This quality assurance project plan template (from EPA 1996, *The Volunteers Monitor's Guide to Quality Assurance Project Plans*) can be used as you develop your Quality Assurance Project Plan for the Department of Environmental Quality (DEQ). Please consult other data users to determine if use of this form (or a modified version) is acceptable to them.

---

## 1. Title and Approval Page

(Project Name) _____	
(Responsible Agency) _____	
(Date) _____	
Project Manager Signature	
	Name/Date
Project QA Officer Signature	
	Name/Date
DEQ Project Manager Signature	
	Name/Date
DEQ QA Officer Signature	
	Name/Date

## 2. Table of Contents

List sections with page numbers, figures, tables, references, and appendices (attach pages if desired).

## 3. Distribution List

Names and telephone numbers of those receiving copies of this QAPP. Attach additional page, if necessary.

I.	_____
II.	_____
III.	_____
IV.	_____
V.	_____
VI.	_____
VII.	_____
VIII.	_____
IX.	_____
X.	_____

## 4. Project/Task Organization

Name	Project Title/Responsibility
	Advisory Panel (contact)
	Project Manager
	QA Officer
	Field/Sampling Leader
	Laboratory Manager/Leader

## 5. Problem Definition/Background

A. Problem Statement

B. Intended Usage of Data

## 6. Project/Task Description

A. General Overview of Project

B. Project Timetable

Activity	Projected Start Date	Anticipated Date of Completion

## 7. Measurement Quality Objectives

### A. Data Precision, Accuracy, Measurement Range

Matrix	Parameter	Measurement Range	Accuracy

### C. Data Representativeness

### D. Data Comparability

### E. Data Completeness

Parameter	No. Valid Samples Anticipated	Percent Complete

## 8. Training Requirements and Certification

### A. Training Logistical Arrangements

Type of Volunteer Training	Frequency of Training/Certification

### B. Description of Training and Trainer Qualifications

## 9. Documentation and Records

## 10. Sampling Process Design

### A. Rationale for Selection of Sampling Sites

B. Sample Design Logistics

	Type of Sample/ Parameter	Monitoring Frequency	Monitoring Period
Biological			
Physical			
Chemical			

**11. Sampling Method Requirements**

Parameter	Sampling Equipment	Sampling Method

**12. Sample Handling and Custody Procedures**

### 13. Analytical Methods Requirements

### 14. Quality Control Requirements

A. Field QC Checks

B. Laboratory QC Checks

C. Data Analysis QC Checks

### 15. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Equipment Type	Inspection Frequency	Type of Inspection	Maintenance Procedure

## 16. Instrument Calibration and Frequency

Equipment Type	Calibration Frequency	Standard or Calibration Instrument Used

## 17. Inspection/Acceptance Requirements

## 18. Data Acquisition Requirements

## 19. Data Management

## **20. Assessment and Response Actions**

## **21. Reports**

## **22. Data Review, Validation, and Verification**

## **23. Validation and Verification Methods**

## **24. Reconciliation with Data Quality Objectives**

# **Appendix 15**

## **Expiration Date of Some Commonly Used Reagents**

**(Courtesy of Alliance for the Chesapeake Bay)**

## Expiration Date of Some Commonly Used Reagents

This Appendix is used by the Alliance for the Chesapeake Bay to determine the expiration date of the reagents used by organizations using the Alliance's protocols for dissolved oxygen and pH measurement.

Assuming that chemicals have been stored properly (cool, dark place- not exposed to long periods of sunlight or heat), the chemicals, even once opened should be good for as long as the shelf life indicated on the bottles. Table 1 lists the maximum shelf life for chemicals used in the LaMotte Dissolved Oxygen and pH test kits).

**Table 1**

Chemicals	Shelf Life (years)
<b>Dissolved Oxygen (LaMotte Winkler Test Kit)</b>	
Alkaline Azide	3
Manganese Sulfate	3
Sodium Thiosulfate	1
Starch	18 months
Sulfuric Acid (and powder)	2
<b>pH (Various LaMotte Test Kits)</b>	
Bromcresol	2
Bromthymol Blue	2
Chlorophenol Red	2
Cresol Red	2
Lamotte Yellow	2
Phenol Red	2
Thymol Blue	2
Wide Range Test Kit	2

## **Appendix 16**

### **Dissolved Oxygen Saturation Concentrations**

## How to Calculate Theoretical Dissolved Oxygen Values

Proper calibration of Dissolved Oxygen (DO) probes is important to collect accurate data. An easy way to see if a probe is calibrated correctly is to compare the probe's results against a theoretical DO value. This value is what the DO level should be based on temperature and barometric pressure.

### DO Level based on temperature

The top table on the attached chart allows users to find the DO level based on temperature. The top and side axis of the table corresponds to the temperature that the probe is reporting. The intersection of the two axes displays the DO reading. Write this number down to start calculating the theoretical DO level.

### Correction factor for barometric pressure

Barometric pressure is a way to tell how much atmosphere is pressing down on a surface. Weather systems and elevation above (or below) sea level can change this value. The bottom table of the attached chart will help compensate for these changes in pressure. Dissolved oxygen probes normally show pressure in millimeters of mercury (**mmHg**) or millibars (**mBar**).

Having a barometer on hand is a good way to get pressure data. A weather station can also provide pressure data. Websites such as [www.weatherunderground.com](http://www.weatherunderground.com) are useful to find local weather stations. Please note that most barometers and weather stations report pressure in inches of mercury (**inHg**).

#### Note about using weather station pressure readings

Weather stations compensate pressure readings to make it appear as if the station is at sea level. To account for this, subtract the barometric pressure by 1.01 inHg per 1,000 feet in elevation of the weather station. This final value is known as **absolute barometric pressure**.

**Example:** Find the absolute barometric pressure of a station located 222 feet above sea level that reported 30.12 inHg.

$$30.12 \text{ inHg} - \frac{1.01 \text{ inHg}}{1000 / 222 \text{ feet}} \rightarrow 30.12 - \frac{1.01}{4.50} \rightarrow 30.12 - 0.22 = 29.90 \text{ inHg absolute barometric pressure}$$

Once finding the absolute pressure, use the bottom table found on the attached chart to find the proper correction factor to use. The formulas at the bottom of the chart will help in converting inHg barometric pressure readings into **millibars (mBar)** or **millimeters of mercury (mmHg)** that are commonly used to calibrate a dissolved oxygen probe. Use this value to find the correction factor to use in the final calculation.

**Example:** A barometric pressure of 970 millibars you would use a correction factor of 0.96 (second column, bottom row).

### Theoretical DO Calculation

To find the theoretical DO value, use the following formula.

$$\text{Theoretical DO} = (\text{DO level based on temperature}) \times (\text{barometric pressure correction factor})$$

**Example:** If a probe had a temperature of 18.4 C and the barometric pressure was 970 mBar, the theoretical DO value would be 9.00 mg/L (9.37mg/L x 0.96 correction factor).

## Dissolved Oxygen Saturation

**Directions-** To determine theoretical DO saturation, multiply the O<sub>2</sub> concentration value (found in the top chart) by the barometric pressure correction factor (bottom chart).

**Example:** Find the DO saturation for at a temperature of **18.4 C** at **730 mmHg** pressure:  $9.37 \times 0.96 = \mathbf{9.00 \text{ mg/L}}$

Temp in °C	O <sub>2</sub> concentrations in mg/l									
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	12.75	12.71	12.68	12.65	12.61	12.58	12.55	12.52	12.48	12.45
6	12.42	12.39	12.36	12.32	12.29	12.26	12.23	12.2	12.17	12.14
7	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.9	11.87	11.84
8	11.81	11.78	11.758	11.72	11.69	11.67	11.64	11.61	11.58	11.55
9	11.53	11.5	11.47	11.44	11.42	11.39	11.36	11.33	11.31	11.28
10	11.25	11.23	11.2	11.18	11.15	11.12	11.1	11.07	11.05	11.02
11	10.99	10.97	10.94	10.92	10.89	10.87	10.84	10.82	10.79	10.77
12	10.75	10.72	10.7	10.67	10.65	10.63	10.6	10.58	10.55	10.53
13	10.51	10.48	10.46	10.44	10.41	10.39	10.37	10.35	10.32	10.3
14	10.28	10.26	10.23	10.21	10.19	10.17	10.15	10.12	10.1	10.08
15	10.06	10.04	10.02	9.99	9.97	9.95	9.93	9.91	9.89	9.87
16	9.85	9.83	9.81	9.79	9.76	9.74	9.72	9.7	9.68	9.66
17	9.64	9.62	9.6	9.58	9.56	9.54	9.53	9.51	9.49	9.47
18	9.45	9.43	9.41	9.39	9.37	9.35	9.33	9.31	9.3	9.28
19	9.26	9.24	9.22	9.2	9.19	9.17	9.15	9.13	9.11	9.09
20	9.08	9.06	9.04	9.02	9.01	8.99	8.97	8.95	8.94	8.92
21	8.9	8.88	8.87	8.85	8.83	8.82	8.8	8.78	8.76	8.75
22	8.73	8.71	8.7	8.68	8.66	8.65	8.63	8.62	8.6	8.58
23	8.57	8.55	8.53	8.52	8.5	8.49	8.47	8.46	8.44	8.42
24	8.41	8.39	8.38	8.36	8.35	8.33	8.32	8.3	8.28	8.27
25	8.25	8.24	8.22	8.21	8.19	8.18	8.16	8.15	8.14	8.12
26	8.11	8.09	8.08	8.06	8.05	8.03	8.02	8	7.99	7.98
27	7.96	7.95	7.93	7.92	7.9	7.89	7.88	7.86	7.85	7.83
28	7.82	7.81	7.79	7.78	7.77	7.75	7.74	7.73	7.71	7.7
29	7.69	7.67	7.66	7.65	7.63	7.62	7.61	7.59	7.58	7.57
30	7.55	7.54	7.53	7.51	7.5	7.49	7.48	7.46	7.45	7.44

### Barometric Pressure Correction factor:

mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor	mmHg (mBar)	Corr. Factor
775-771 (1033-1028)	1.02	750-746 (1000-995)	0.987	725-721 (967-961)	0.953	700-696 (934-928)	0.92
770-766 (1027-1021)	1.014	745-741 (994-988)	0.98	720-716 (960-955)	0.947	695-691 (927-921)	0.914
765-761 (1020-1014)	1.007	740-736 (987-981)	0.973	715-711 (954-948)	0.94	690-686 (920-915)	0.907
760-756 (1013-1008)	1	735-731 (980-975)	0.967	710-706 (947-941)	0.934	685-681 (914-908)	0.9
755-751 (1007-1001)	0.993	730-726 (974-968)	0.96	705-701 (940-935)	0.927	680-676 (907-901)	0.893

## **Appendix 17**

# **Commonly Used Formulas for Water Quality Monitoring**

**Metric Units**

1 <b>kilo</b> (grams, meters, etc.)= 1,000 (grams, meters, etc.)	1 (gram, meter, etc.) = 0.001 <b>kilo</b> (gram, meter, etc.)
1(gram, meter, etc.) = 1,000 <b>milli</b> (gram, meter, etc.)	1 <b>milli</b> (gram, meter, etc.)= 0.001 (gram, meter, etc.)
1 <b>kilo</b> (gram, meter, etc.) = 1,000,000 <b>milli</b> (gram, meter, etc.)	1 <b>milli</b> (gram, meter, etc.) = 0.000001 <b>kilo</b> (gram, meter, etc.)

**Weight**

1 pound = 453.59 grams	1 gram = 0.002205 pounds
1 kilogram = 2.205 pounds	1 pound = 0.4535 kilograms

**Volume**

1 cubic foot (ft <sup>3</sup> )= 7.48 gallons	1 gallon = 0.1337 cubic foot (ft <sup>3</sup> )
---	---

**Length**

1 mile = 5,280 feet	1 foot = 0.0001894 mile
1 meter = 3.28084 feet	1 foot = 0.3048 meter
1 mile = 1.609 kilometers	1 kilometer = 0.6214 mile

**Specific Characteristics of Water**

1 gallon = 8.34 pounds	1 pound = 0.12 gallon
1 gallon = 3.783 liters	1 liter = 0.26417 gallon
1 liter = 1 kilogram	1 kilogram = 1 Liter
1 gallon = 3.783 kilograms	1 kilogram = 0.26417 gallon
1 liter = 2.205 pounds	1 pound = 0.4535 liters

**Barometric Pressure**

1 inHg = 25.4 mmHg	1 inHg = 33.8 millibars (mBar)
--------------------	--------------------------------

**Temperature**

$Celsius = \frac{5}{9} \times (Temp\ ^\circ F - 32)$	$Fahrenheit = (\frac{9}{5} \times Temp\ ^\circ C) + 32$
--	---

**Basic Geometry**

a. Circumference	$C = 3.1416 \times \text{Diameter}$
b. Perimeter	$P = (2 \times \text{Length}) + (2 \times \text{Width})$
c. Area	
Rectangle	$\text{Area} = \text{Length} \times \text{Width}$
Circle	$\text{Area} = 0.785 \times \text{Diameter} \times \text{Diameter}$
Triangle	$\text{Area} = \frac{1}{2} \times \text{Base} \times \text{Height}$
d. Volume	
Rectangle	$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth}$
Cylinder	$\text{Volume} = 0.785 \times \text{Diameter} \times \text{Diameter} \times \text{Depth}$
Cone	$\text{Volume} = 0.262 \times \text{Diameter} \times \text{Diameter} \times \text{Height}$
Sphere	$\text{Volume} = 0.524 \times \text{Diameter} \times \text{Diameter} \times \text{Diameter}$

**Calculating Flow**

a. Million Gallons per Day (MGD) to Gallons Per Day (GPD)	$\text{Flow, GPD} = \text{Flow, MGD} \times 1,000,000 \text{ gallons / MG}$										
b. MGD to Gallons per Minute (GPM)	$\text{Flow, GPM} = \frac{\text{Flow, MGD} \times 1,000,000 \text{ gallons / MG}}{1,440 \text{ minute / Day}}$										
c. MGD to Cubic Feet per Second (CFS)	$\text{Flow, CFS} = \text{Flow, MGD} \times 1.55 \text{ CFS / MGD}$										
d. CFS to MGD	$\text{Flow, MGD} = \text{Flow, CFS} \times 0.645 \text{ MGD / CFS}$										
e. Flow (Velocity), CFS	<p>Using a float: <math>\text{Flow} = \text{ALC} / \text{T}</math></p> <p>Using a flow meter: <math>\text{Flow} = \text{AMC}</math></p> <p>Where:</p> <table border="1"> <tr> <td>A =</td><td>Area of stream (average stream depth x stream width)</td></tr> <tr> <td>L =</td><td>Distance covered by float run</td></tr> <tr> <td>M =</td><td>Measured flow rate based on average flow meter readings</td></tr> <tr> <td>C =</td><td>0.9 if the streambed is smooth (silt, sand, or bedrock) 0.8 if the streambed is rough (rubble, stones, gravel)</td></tr> <tr> <td>T =</td><td>Average time of float run</td></tr> </table>	A =	Area of stream (average stream depth x stream width)	L =	Distance covered by float run	M =	Measured flow rate based on average flow meter readings	C =	0.9 if the streambed is smooth (silt, sand, or bedrock) 0.8 if the streambed is rough (rubble, stones, gravel)	T =	Average time of float run
A =	Area of stream (average stream depth x stream width)										
L =	Distance covered by float run										
M =	Measured flow rate based on average flow meter readings										
C =	0.9 if the streambed is smooth (silt, sand, or bedrock) 0.8 if the streambed is rough (rubble, stones, gravel)										
T =	Average time of float run										

**Laboratory Equations**

<b>Converting mg/L Results</b>	
a. mg/L to Pounds/Day	Pounds/Day = Result, mg/L x Flow, (MGD) x 8.34 lbs (MG/mg/L)
b. mg/L to Kilograms/Day	Kilograms/Day = Result, mg/L x Flow, (MGD) x 3.785 lbs (MG/mg/L)

<b>Quality Assurance</b>	
a. Relative Percent Difference (duplicate samples)	$RPD\% = \frac{\text{Absolute Value (Sample1- Sample2)}}{\text{Average (Sample1+ Sample2)}} \times 100\%$
b. Probe Slope	Slope (millivolt change) = Standard value 2 – Standard value 1

<b>Dissolved Oxygen</b>	
Winkler Titration	$DO, \text{ mg / L} = \frac{\text{Titrant, mL} \times \text{Normality(N)} \times 8,000}{\text{Equivalent Sample Volume, mL}}$ <p>If N = 0.0250 &amp; Sample Volume = 200 mL then : mL Titrant Used = DO, mg/L</p>

<b>Bacteria (E. coli, Enterococcus, etc.)</b>	
a. Multiple Tube, Colilert, etc.	$MPN / 100 \text{ mL} = MPN_{chart} \times \frac{\text{Sample Volume In First Dilution}_{chart}}{\text{Sample Volume in First Dilution}_{sample}}$
b. Membrane Filtration, Coliscan, etc.	$Colonies / 100 \text{ mL} = \frac{\text{Colonies Counted}}{\text{Sample Volume , mL}} \times 100 \text{ mL}$
Geometric Mean (if collecting more than one sample per month)	$GeometricMean = \sqrt[n]{Test_1 \times Test_2 \times Test_3 \dots \times Test_n}$